

Chemical Engineering Progress

January 1954



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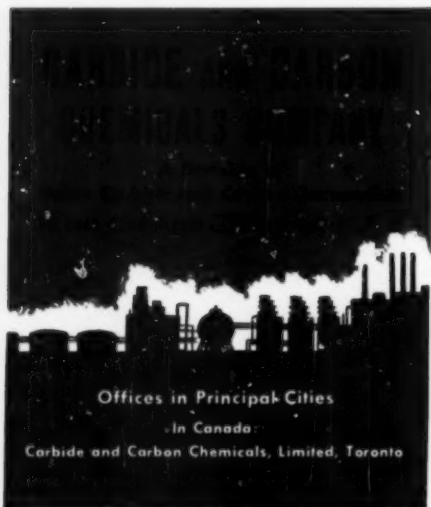
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Chemical Engineering Progress

JANUARY, 1954

Volume 50, No. 1

Editor: F. J. Van Antwerpen

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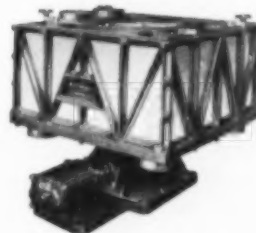
- 4A • 8A LETTERS TO THE EDITOR
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Advertising Manager: L. T. Dupree

The cover this month comes as close as possible, artistically and alchemically, to expressing the import and content of the lead article on low-temperature carbonization. The background photograph, courtesy Bituminous Coal Institute, shows the origin of coal, the alchemistic shorthand represents fire applied to earth to form oil (couldn't find a symbol for gas), and the benzene rings are a much simplified coal molecule.

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LETTERS TO THE EDITOR

The Pursuit of Health

In the article on the "Design and Use of Ten-Kilocurie Source of Gamma Radiation" (*CEP*, Nov., 1953), nowhere can I find any indication of an interest on the part of the authors in possible nutritional changes in food processed. Granting that this consideration may be premature but recognizing that much of our food is over-refined, I wish to point out what has often been said and as frequently overlooked—that progress has been impeded by errors of omission as well as commission.

This is not a purely academic matter. As an example, innumerable reports in publications including the *Journal of the American Medical Association* have shown the biochemical advantages of certified raw milk over pasteurized milk. Therefore, any improved method of neutralizing bacteria without affecting nutrients in milk would be an improvement allowing us to approach more closely the optimum level of health, not merely the present average level.

LEWIS S. MEYERS

Cranford, N. J.

Values for Aromatic Hydrocarbons Corrected

In the article "Heat Capacity of Organic Liquids" by W. M. Chow and John A. Bright, Jr., which appeared in the April, 1953, issue of *CEP*, there are a number of discrepancies in heat capacity data quoted in Tables 3 and 6.

In correspondence with the authors, it was revealed that the heat capacities in Table 3 were not all at 20° C. but were taken at the nearest temperature readily available at the time. Later, when working with the variation of heat capacity with temperature, they used more nearly correct data for the temperatures stated.

These discrepancies are serious for the aromatic compounds while for other com-

(Continued on page 8A)





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Power and Steam Plants	Tanneries
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The new Nordstrom Corrosion-Resistant Valve Bulletin V-217 will make it easy for you to fit the right valve to each service. Write for a copy, Rockwell Manufacturing Company, Pittsburgh 8, Pa., or ask your Nordstrom sales engineer.



Nordstrom three-way
Transflo valves on
relief service at top
of propylene tower
separating propylene
from propane.

-Sealed for POSITIVE SHUT-OFF"

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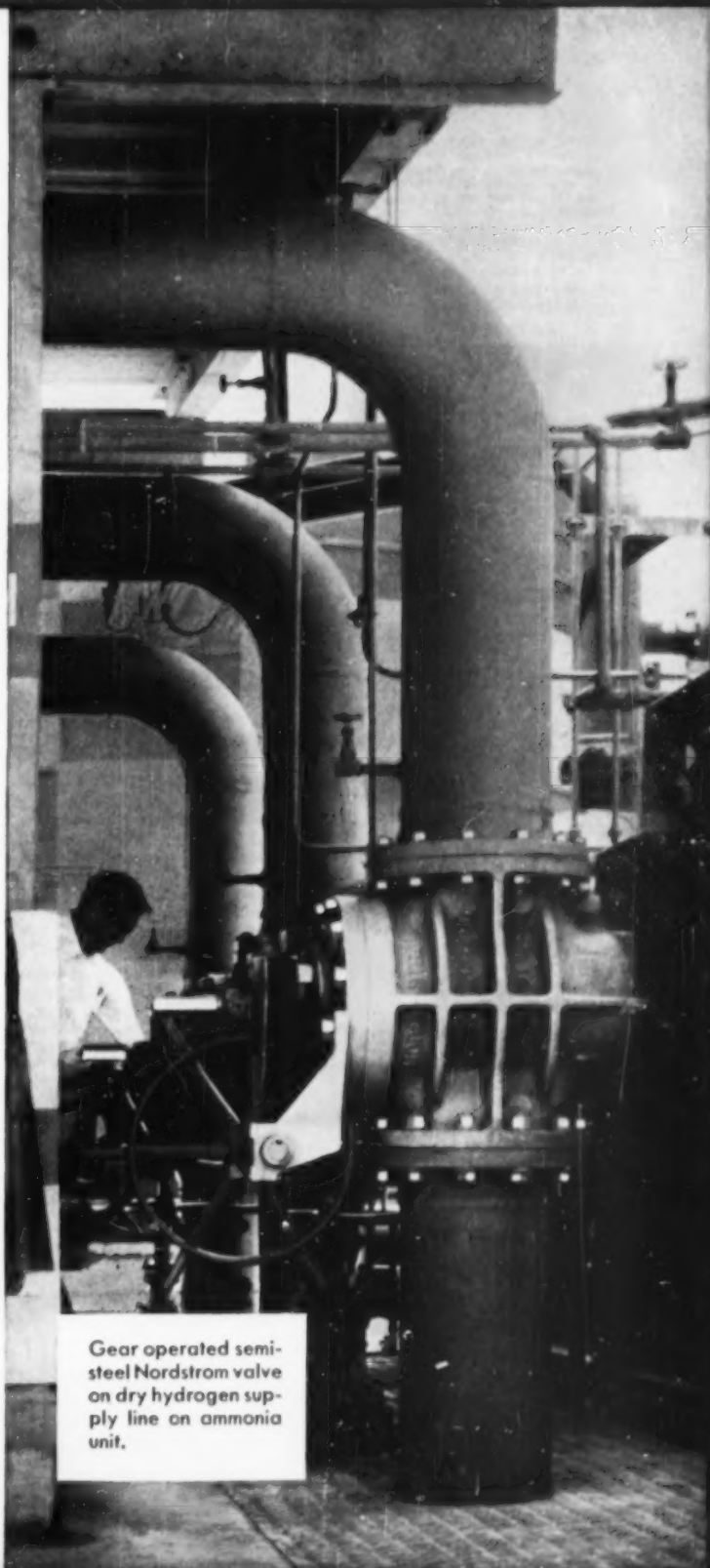
That, of course, means greater safety, and greater economy, too, because when leakage is prevented, valve life is far longer. And most important, it means uninterrupted operation of continuous process units—no down-time for avoidable valve repairs.

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LETTERS TO THE EDITOR

(Continued from page 4A)

pounds they are probably not significant. Because of these errors in the data used to evaluate constants A and B in Equation (3), the values stated in Table 2 are not correct for aromatic hydrocarbons.

For aromatic hydrocarbons, I have calculated a value of 19.8 for A and +8 for B to be used in place of the values stated in Table 2. These revised constants were determined from the best available data at 20° C. for five aromatics.

HAROLD C. RIES

Engineering School
Tufts College

Approval from Foreign Student

As a long-time foreign student in this country, under fellowships from the Turkish Government (1945-52), Phillips Petroleum Company (1952-53), and DuPont (1953-54), I would like to attempt to answer briefly part of your "note" to "Life at an American University" in the November, 1953, issue of *Chemical Engineering Progress*.

The best and most interesting parts of the engineering education in this country, I find, are:

1. Wide acceptance of the four-year curricula over the five- or six-year ones. This probably is the answer to a more productive and efficient engineering education in many foreign countries.
2. Many teachers are practical minded; they assign homework constantly. This, perhaps, is the sine qua non of successful engineering teaching.
3. Schools are so numerous that it is impossible for a student not to find the college he likes.
4. Flexibility, due to "electives," plays an important part in student's success.
5. Close contact with professors—a unique feature of the American system—is very interesting to a foreigner; he will talk about it perhaps all his life.
6. Wide variety of social activities makes college life interesting and desirable.

I believe that the American system is superior to many others if the purpose is to meet the demand of the country for engineers and not to graduate excellent students alone.

Perhaps the most unpleasant part of the system is that one has to pay large sums of money to attend a college. However, most Americans seem to be able to afford it. Therefore, it may not be so bad.

ERDEM M. ATADAN

Department of Chemical Engineering
University of Tennessee

Decline in Liberal Arts Courses Deplored

Item b, Table 5, page 56, *CEP*, October, 1953, is appalling. Recommended reading: *Saturday Review*, Nov. 21, 1953, pp. 32 to 46.

EDWARD R. MCCARTNEY

Altadena, Calif.

January, 1954



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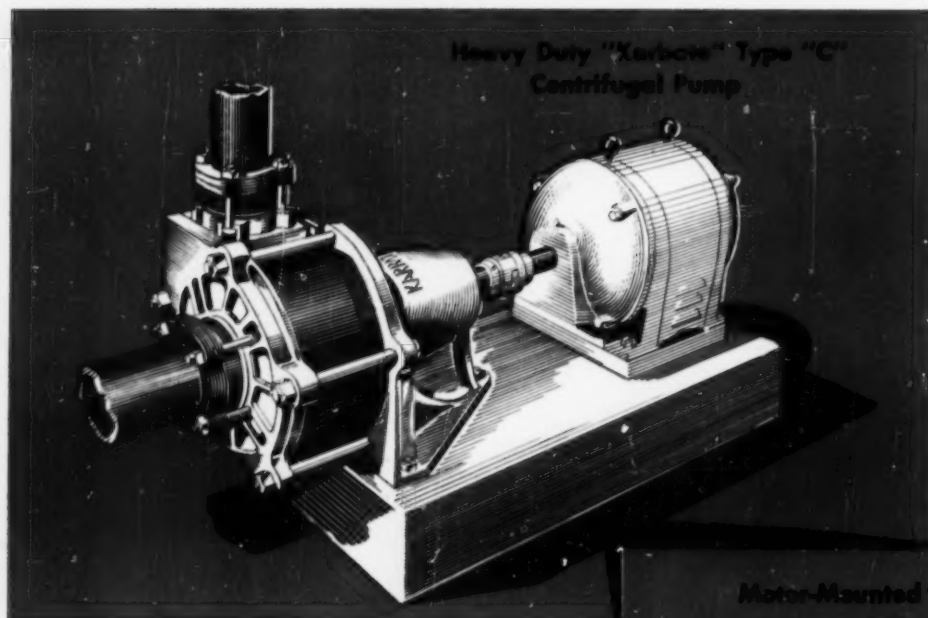
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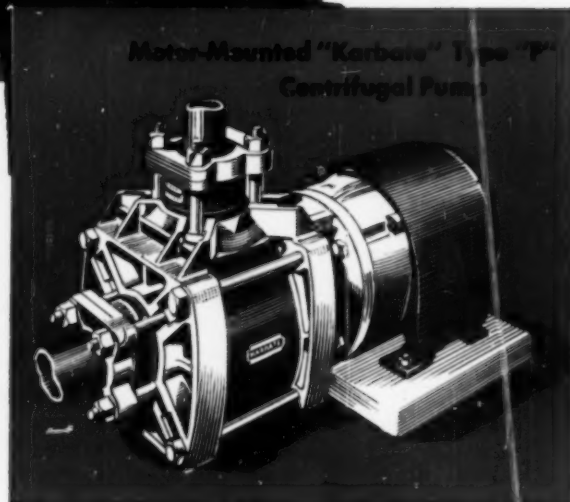
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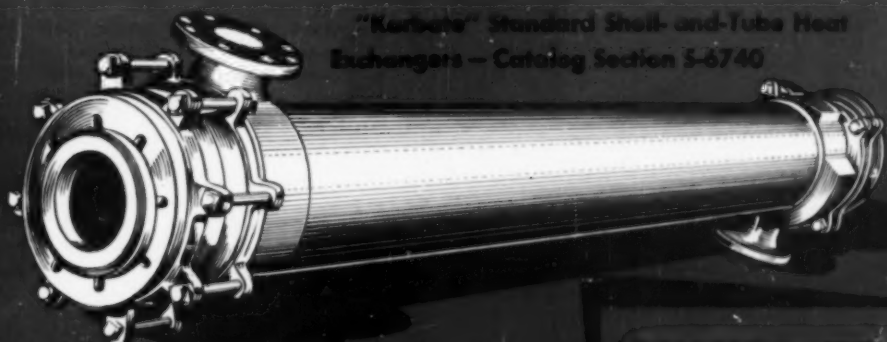
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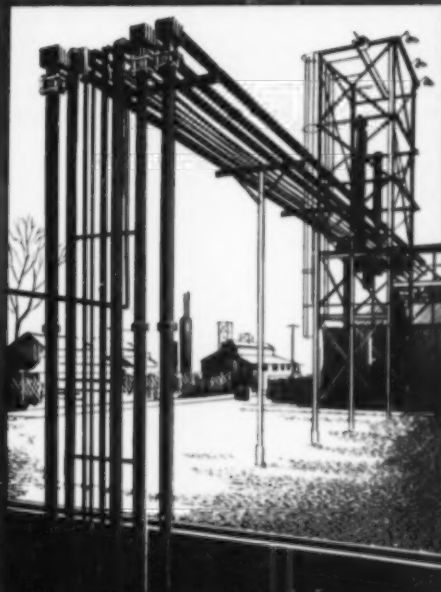
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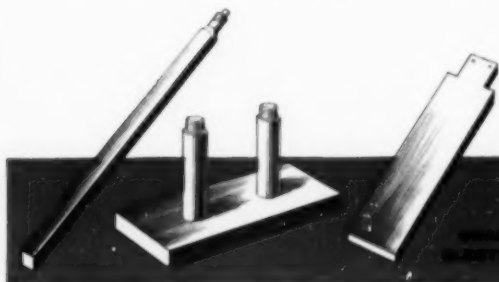
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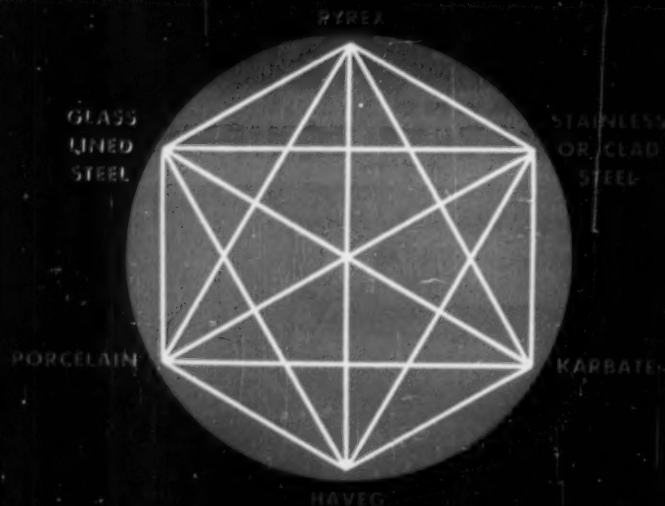
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NOTED AND QUOTED



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When the history of our era is written it may be that the last fifty years will be seen as a mere transitional period, during which a country rose suddenly to overwhelming wealth and power, built the framework of a vast educational system, committed many aberrations because of the size and complexity of its undertakings and the novelty of its problems, but always cherished the underlying convictions that were to come to flower in the next phase of its development. In that phase substance will be given to the forms, direction will be given to the machines, that have been designed in the transitional era of construction and expansion. That substance and direction can be drawn from the deepest values of America and the West.

In the long painful journey to Utopia the American people have their own tradition, their own genius, their own spirit to guide them.

Robert M. Hutchins
in "The University of Utopia"

Industrial Revolution II

Per unit of population the United States employs far more scientists and engineers than we [Great Britain] do. This reflects both a greater belief in research and development, and the greater diversity of its industry. Until the number of scientists and engineers employed in our own industry is greatly increased and their average quality improved, we shall continue to lag behind. Their distribution within industry also needs to be greatly improved.

Sixth Annual Report of the
Advisory Council on Scientific Policy
London, England

Banzai to Farmers

The Japanese farmer has been liberated by chemicals from the manual labor of weeding. In the past, most Japanese farmers have become bent with age from years of weeding in a stooped position. In the future, there should be no bent farmers in Japan. In other words, American chemical weedkillers are straightening the posture of the Japanese.

Hohei Suematsu
Nissan Chemical Industries, Ltd.
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CA=Q

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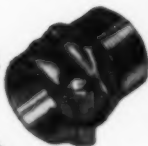


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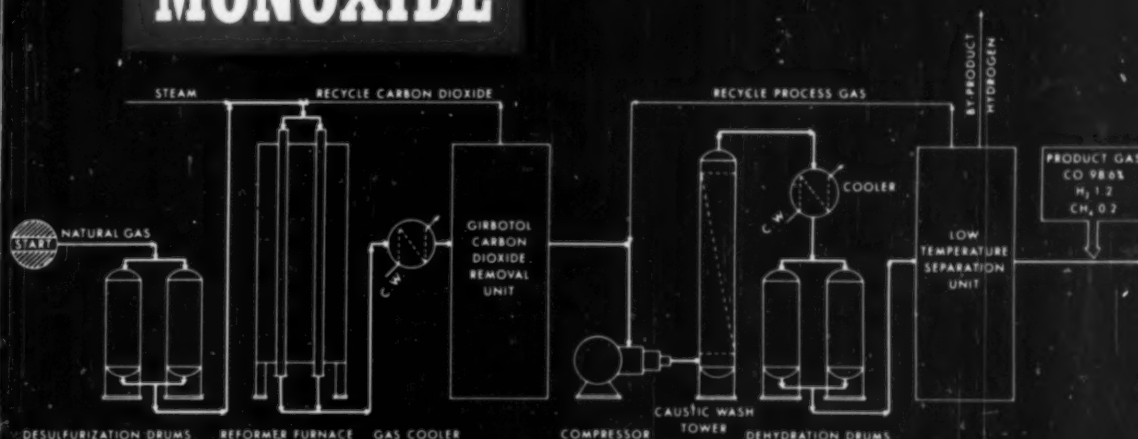
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ROHM & HAAS CARBON MONOXIDE UNIT



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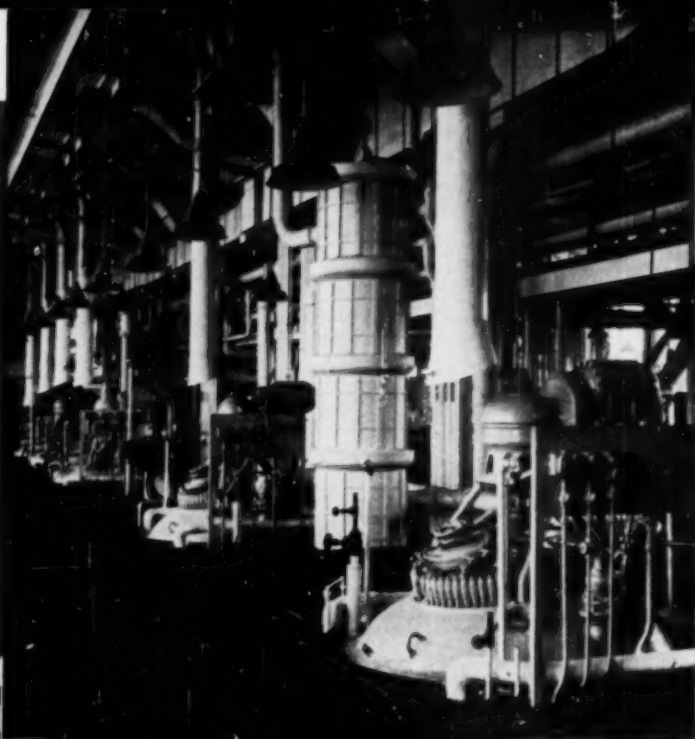
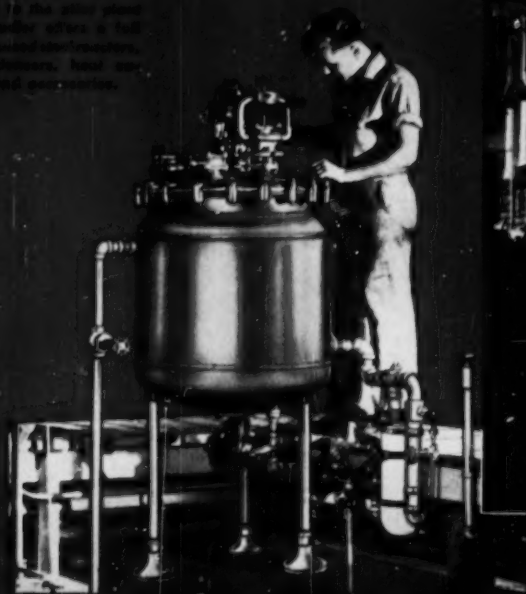
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Opinion and comment

PLANS FOR 1954

The custom of having the President of A.I.Ch.E. present the January "Opinion and Comment" affords me the opportunity to inform you briefly of the more important plans for 1954. The membership of the Institute is growing at a rapid rate as the following tabulation shows:

Year	Total Members
1930	880
1937	1,450
1940	2,300
1950	7,700
1953	13,500

If this average rate of growth continues, the Institute will double in size approximately every seven years. We see no reason to believe that this rate of growth will not continue. Hence, we expect the following:

Year	Total Members
1960	22,000
1963	30,000
1970	60,000

It is apparent that so rapid a rate of growth presents serious problems. Furthermore, the larger A.I.Ch.E. becomes, the more acute these problems become in a given time period. Between 1940 and 1950 our membership increased about 5,400, but between 1950 and 1960 we expect an increase of 14,300. Even with the same service functions being furnished the membership, it would seem certain that a far greater expansion in paid staff will be necessary between 1950 and 1960 than was required between 1940 and 1950. This also calls for a corresponding expansion in housing facilities.

However, it is probable that the service functions will be expanded rather than fixed at the 1940-1950 level. As a matter of fact at the December meeting, Council appropriated the necessary funds to start a new journal for the publication of those papers which form the backbone of the profession. The new journal will publish the highly technical mathematical, design and scientific papers. It will probably not carry much advertising and, therefore, it may be necessary to charge a nominal subscription rate to finance, partially, this new publication venture. *Chemical Engineering Progress* will carry news and articles of a more general nature. It will continue to have advertising and will be supplied to all members as at present. Getting this new publication started will be a major accomplishment.

Obviously, such an expansion in services, together with the rapidly expanding membership adds to the housing problem. This latter problem can probably be solved only on a temporary basis during 1954. A more fundamental solution to the problem is being developed in cooperation with the other engineering societies. The objective of this study is to establish an engineering center in some convenient city to house these

engineering societies together. Locations as far west as Chicago are being considered at present.

On Dec. 31, 1954 our beloved Executive Secretary, Stephen L. Tyler, retires. It is essential, therefore, that we make a decision early in 1954 with regard to Mr. Tyler's successor. This Executive Secretary-elect will have much to do to get himself prepared to take over the chief executive's duties. In all probability, too, these duties will have to be enlarged because there are many services now being rendered by volunteer help which soon will have to be handled by paid staff. This is merely one of the prices to be paid for expanding membership.

Those who attended the St. Louis meeting learned that there is active consideration by Council of a revision in grades and privileges of membership. This, of course, would require an amendment to the Constitution. The new grades of membership being considered are Member, Associate Member, and Affiliate. The Member grade is identical with the present Active Member grade. The Associate Member grade would include the present Junior Member grade and the present Associate Member grade except Article III, Section 3, paragraph (d). This section describes what would be the Affiliate grade.

Perhaps the most important argument in favor of changing to these classifications of membership is that they are the classifications recommended by E.C.P.D. It would seem advantageous to have standard grades of membership in the different engineering societies.

The proposal under consideration also involves extension to the Associate Member grade of the right to nominate and vote for officers and directors. The right to vote on changes in the Constitution would be confined to the Member grade. There is strong feeling on the part of many that it would be far healthier for the profession if the present grade Junior Members were permitted to vote in nominations and elections of officers and directors. Such a change presents a few problems such as dues adjustments. But by basing the dues rate on age as well as membership grade it is possible to arrive at an effective solution to these problems. It is not planned at present to increase the dues although there will be individual adjustments.

Another proposal under active consideration by Council is a revision in the nominating procedure for officers. Six men were nominated for vice-president in 1954 but four of them declined. It would have put us in an embarrassing position had all six declined. Council has recognized this as a bad situation and is setting up a nominating procedure to be recommended to the active membership for adoption. The proposal under consideration would require an amendment to the Constitution.

In closing it is well to emphasize that every effort is being made to improve the professional status of the A.I.Ch.E. membership. It is through this channel we believe that the economic status of the chemical engineer can be enhanced most effectively.

C. G. KIRKBRIDE
President, A.I.Ch.E.

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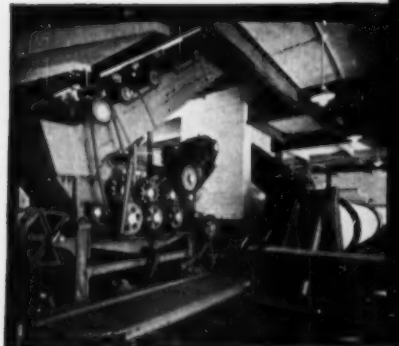
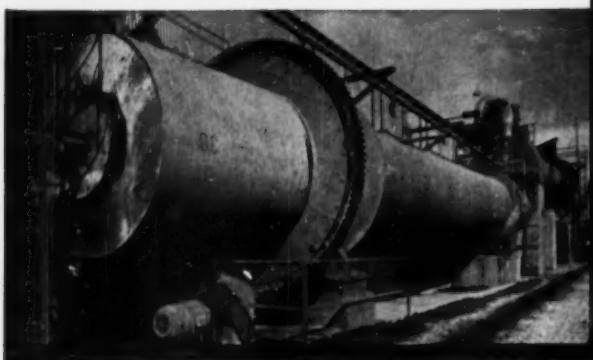
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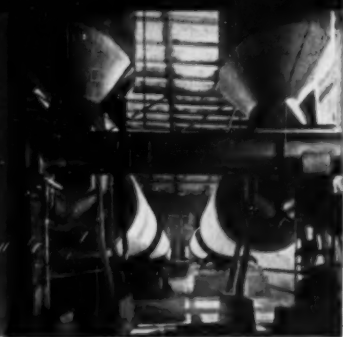
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Application of Low-Temperature Carbonization

Robert E. Zinn

Northwestern University, Evanston, Illinois

Robert E. Zinn is a professor of chemical engineering, The Technological Institute, Northwestern University, Evanston, Ill., and presently associated with the Vern E. Alden Co., Chicago, Ill., as a consulting chemical engineer. On joining the Technological faculty in 1951, he terminated twenty-four years' employment with the Victor Chemical Works, Chicago Heights, where he began as a junior chemical engineer in 1927 and rose to the position of chief chemical engineer and later to chief engineer.

Zinn received his bachelor's degree in chemical engineering from the University of Wisconsin with honors in 1927. He is past chairman of the Chicago Section of A.I.Ch.E. and belongs to the American Society of Mechanical Engineers, Western Society of Engineers, and the National Association of Corrosion Engineers.

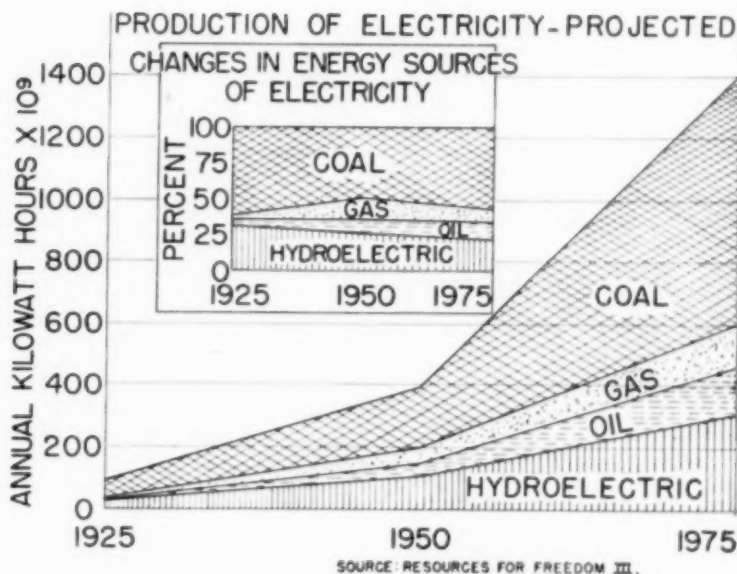


Fig. 1.

The Western World is constantly facing new problems in maintaining survival, and one of the principal ones is the slow but definite using up of our resources of petroleum and natural gas, as well as hydropower. The current report of the President's Materials Policy Commission (6) predicts that by 1975 our energy requirements in thermoelectrical capacity will have increased from 400,000,000 kw. to 1,400,000,000 kw. (Fig. 1). Even with doubling the capacities of hydropower and the use of natural gas and oil in the production of electric power, it becomes necessary to expand the use of coal for the production of electricity by more than three times its current use in order to meet these predicted requirements for energy.

In order to meet these demands for energy requirements, supplies of high-grade coals should not unwisely be exhausted. Rather should efforts be concentrated on the use of low-grade subbituminous and lignite coals through upgrading by the application of chemical processes and reactions. The low-temperature-carbonization process is the outstanding method for upgrading these solid fuels.

Low-temperature carbonization is generally understood to be the destructive distillation of coal in the temperature range of 450° to 700° C. (9) (Fig. 2). At these temperatures and under desirable processing conditions there is a minimum decomposition of volatile matter with a relatively low yield of gas and a maximum yield of tar and oil distillate. The coke residue (char) may contain volatile matter up to about 25 or 30%, reported to be noncondensable or gaseous volatile.

The heat distribution in the low-temperature-carbonization process will vary with the quality of the coal or lignite. Results from this author's experiments indicate that for the processing of lignite, about 75% to 80% of the heat content of the raw lignite will be present in the char product. Table 1 shows the approximate distribution of this heat and related material costs.

The principal process now in use for the coking of coals is that using by-product coke ovens. This is referred to as high-temperature carbonization (900° to 1200° C.). The high-temperature process gives a maximum decomposition of volatile matter with a relatively high yield of gas and a minimum quantity of tar distillate. The coke residue from the high temperature process is usually hard abrasive mate-

Professor Zinn, in addition to his affiliation with Northwestern University, is also with Vern E. Alden Co., Chicago, Ill.

rial with considerable strength which allows its use in metallurgical furnaces.

The technique of making low-temperature coke is different, however, since both coal and low-temperature coke are poor conductors of heat compared to high-temperature coke. The process for making low-temperature coke is quite different from the high-temperature process with the customary slot ovens. Coal placed in these slot ovens in contact with the hot refractory wall is rapidly converted to high-temperature coke. This high-temperature-coke layer next to the hot refractory wall then transmits heat to the adjacent coal to convert into high-temperature coke and the resulting two layers of coke transmit heat from the hot refractory to the next succeeding layer of coal and so on until the coking process has proceeded from both sides to the center of the mass of coal charged. However, if the walls in the slot oven were only 500° or 600° C. instead of more than 1000° C. no coke would be made with a high coefficient of heat conductivity and thus the use of a conventional by-product oven for the low-temperature carbonization of coal would require an interminably long time for coking the charge across the customary 18-in. wide slot. Even if the slots are reduced in thickness, this time is still appreciable and, of course, with reduced slot thickness the capacity of the equipment is reduced substantially. Mr. Leshner says (4),

It is this factor that has intrigued a thousand inventors—to build a machine to overcome the reluctance of coal to be heated sufficiently and no more—and to give a product technically called 'primary coke.' The technical literature of low temperature coke abounds in classifications and descriptions of methods and processes with claims for external versus internal heating—direct versus indirect—horizontal versus vertical retorts—intermittent versus continuous processes.

Past and present interest in the use of low-temperature carbonization has been stimulated by the low-cost production of coke that can be realized with this process. Since the low-temperature-carbonization process does not require the use of high-temperature refractory installations, the capital investment required for a plant of equal capacity is much less than for the high-temperature process. Further, since a lower temperature is required, the operation cost is reduced because less heat is required for carbonization. Also, in low-temperature-carbonization processes using fluidizing techniques, both equipment and operating costs can be reduced. The latter operation will permit the use of low-temperature carbonization in connection with a

power plant as an automatic integrated unit. This application of low-temperature carbonization to the production of power from solid fuel is at present under development on a commercial scale, and designs are nearing completion for additional units. These integrated units would use low-temperature carbonization to up-grade a portion of the subbituminous coal or lignite to more valuable by-products, the sale of which will furnish sufficient income to pay for a substantial portion of the cost of the fuel for power generation.

Economic advantages of the low-temperature-carbonization process result from the up grading of the heat equivalent of the distillate produced from the original coal or lignite. The market value of the tar and oil distillate may be about 30 to 35 cents/million B.T.U. If it is assumed that strip-mined lignite can be delivered without a railroad freight charge to a point of use near the mining operation at a unit cost of 8 cents/million B.T.U., the economic

advantages of low-temperature carbonization will be high. If, however, coal is used from an underground mining operation at a delivered cost of 20 cents /million B.T.U., the net gain from low-temperature carbonization may be modest and likely not worth consideration.

It is almost certain that the unit costs of mining coal and lignite will increase in the future. This increase in fuel cost will result in a higher cost of power generated in most steam-power stations. In contrast to this the favorably located steam-power station integrated with a low-temperature carbonization plant will have the advantage that the residual cost of char used for fuel will be low and that this residual cost will decrease as the market price of the recovered tar and oil distillate tends to increase.

Factors which represent advantages for the low-temperature-carbonization processes in contrast to high-temperature carbonization include increased yield of distillate, less decomposition of

Fig. 2.

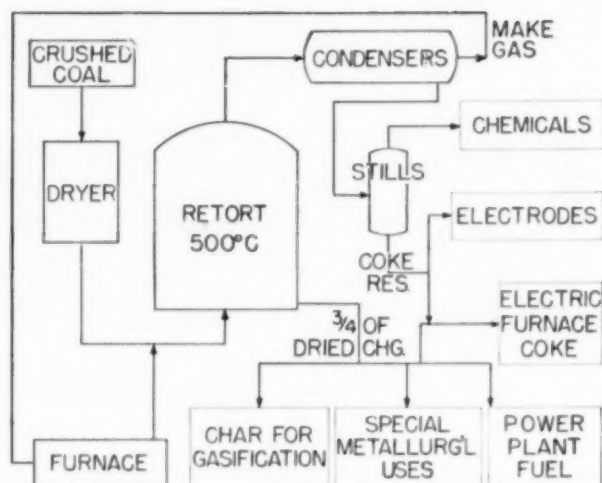
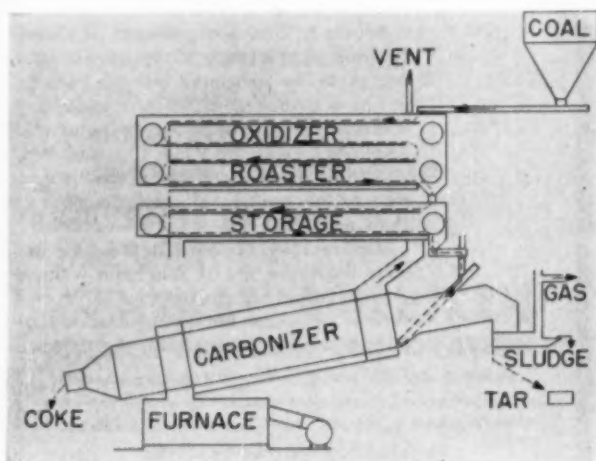


Fig. 3. Disco process.



the distillate, and an easier and improved method for providing complete gasification of coals. Because of lower installation and operating costs than for the high-temperature process, the low-temperature process is used to produce low-cost smokeless fuel from high volatile coals which burn in ordinary domestic and small commercial furnaces with enormous quantities of smoke and soot. Also, the low-temperature process has a cost advantage for providing carbon char or carbonaceous gases to produce synthetic chemicals with or without complete gasification of the coal or with subsequent hydrogenation and reforming techniques.

In spite of the several advantages mentioned, the engineer must realize that the use of low-temperature carbonization has its difficulties. At the present time there are only a few small-to-medium size commercial installations in operation and these are concerned mainly with the production of smokeless fuel for domestic use or semicoke for admixing with materials to produce high-temperature coke for metallurgical furnaces. Much of the difficulty during this period related to handling the materials in the process, particularly the removal of the char or coke that expanded within the equipment and retained some of the plasticity that is usual in this temperature range.

In recent years fluidization techniques have been applied to the low-temperature processes for the production of granular char or coke. It is believed that the greatest factor contributing to the present indicated successful development of low-temperature-carbonization processes for making a granular char is the use of fluidization techniques throughout the process. Though the use of fluidization is particularly advantageous with non-coking coals and lignites, there

are indications that it can be applied successfully to coking and caking coals if the material is first subjected to partial oxidation such as is used in the Disco process (7) and in the precommercial units of the Singh process (8).

From the standpoint of the products of low-temperature-carbonization processes there are certain other disadvantages as follow:

1. The char produced is either a noncoking material or it has such physical nature as to make it unsuitable for use as metallurgical coke.
2. Distillation products from low-temperature carbonization are new and different in physical and chemical properties from the corresponding products of the high-temperature-carbonization process. Thus it is necessary to develop uses and markets for the sale of these new low-temperature tars.
3. A sudden gigantic over-production of tars and light oils from the too rapid development of low-temperature carbonization could depress the commercial acceptance of low-temperature-carbonization processes.

A number of processes and equipment devices for low-temperature carbonization have been created over the past half-century and more than a hundred of these processes have been patented. It will be recalled that the carbonization process is mainly one of heat addition or heat transfer. These processes can be classified as static or dynamic, depending on whether or not the coal is in motion during carbonization. They can be further classified according to the method of heating the coal during carbonization. For example, a carbonization retort can be heated externally or internally through a heat-transfer wall or flue. Further, the heat for carbonization can be supplied by circulating or passing a hot gas through the material being processed, or the

coal can be heated by mixing it with solids, such as char at a higher temperature.

Although the experience with brown coals had been commercially successful in Germany during World War II, the adoption of these processes in this country without sufficiently considering the difference in the characteristics of the coals to be processed has resulted generally in a series of catastrophic failures. It should be pointed out, however, that recent developments on the semiplant scale have appeared to be favorable, and it is anticipated that some of the installations now under construction or under design will be commercially successful.

Two of the indirect heating processes, one being used and the other considered for commercial application, are the Disco process and the Hayes process.

1. The Disco process (6) uses an externally heated revolving cylinder or kiln about 8 ft. in diam. and 150 ft. long (Fig. 3), including a pretreatment with partial oxidation and admixing of recycled char with the feed material.
2. The Hayes process (3, 10) uses a horizontal rotating cylindrical retort about 20 in. in diam. by 20 ft. long, with an internal reversing scraper-screw. (Fig. 4).

Some of the processes that have been developed for the low-temperature carbonization of coal by direct heating include the Lurgi-Spülgas process, the National Fuels Corp. process, the Parry process and the Singh process.

1. In the Lurgi-Spülgas process (3) the necessary heat of distillation is furnished by hot circulating gases penetrating the briquetted coal charge of temperatures between 600° and 700° C. (Fig. 5).
2. The National Fuels Corp. process is similar in many ways to the Lurgi-Spülgas process (3) just described (Fig. 6), except that the heating is accomplished with the gas distilled from the coal itself instead of using combustion gases or superheated steam, thus avoiding gas dilution of the distillation products.
3. The Parry process (5) (Denver Station of the U. S. Bureau of Mines) begins with a flash drying of crushed coal or lignite in a high-velocity fluidized bed which carries the dried coal over to a collecting cyclone (Fig. 7). The dried coal from this receiver is then fed to the bottom of an externally heated vertical retort which is operated at about 500° C. Air is used for fluidizing the coal and additional amounts of air (up to about 60% of the heat equivalent required) are used to gain increased capacity.
4. The Singh process (2) uses a fluidized bed of crushed coal as a dryer or oxidizer (Fig. 8), followed by a devolatilization retort from which the destructive distillation pro-

Table 1.—Approximate Heat Distribution for Low-Temperature Carbonization of Lignite

	Percent of Heating Value of Undried Lignite
Required for Drying Wet Lignite	
Heat available from make gas	4 to 5%
Additional heat required from char	2 to 3%
Total heat for drying	6 to 8%
Required for Devolatilization	
Heat supplied from partial oxidation of char	About 3%
Available Products	
Heat content of tars and oils	7* to 15%**
Heat content of char products	75* to 80%**

* Using these minimum quantities with lignite delivered at 8¢ and a tar-oil value of 30¢ per million B.t.u., the heat cost of the char is:

$$\frac{8.00 - (30 \times 0.07)}{0.75} = 7.87¢.$$

** Using these maximum quantities with lignite delivered at 8¢ and a tar-oil value of 35¢ per million B.t.u., the heat cost of the char is:

$$\frac{8.00 - (35 \times 0.15)}{0.80} = 3.43¢.$$

ducts are removed and condensed without appreciable carry-over of the fluidized solid. Heating is accomplished by withdrawal of a portion of the char to a third retort wherein the temperature of the char is raised by slight partial oxidation and returned as a fluidized solid to heat the devolatilization retort.

Applications

Among the applications that may be considered for low-temperature carbonization as a tool of the chemical engineer with a processing cost advantage are the following:

FUEL FOR STEAM ELECTRIC POWER

Use of low-temperature carbonization for processing the fuel used for the production of steam for electric power has been considered for more than a quarter of a century. Thus far there have been no successful commercial installations in operation although two have been proposed recently and one of these is under construction. The latter refers to the installation of the Parry process (5) of the U. S. Bureau of Mines by Texas Power & Light Co. in conjunction with an aluminum reduction plant under construction for the Aluminum Company of America in Milan County, Tex.

The other recent proposal of low-temperature carbonization to be applied to the large-scale production of electric power was made to the Atomic Energy Commission by the Vern E. Alden Co. in April, 1952. It was revealed (7) that with three 800,000 kw. power stations adjacent to the huge lignite deposits in North Dakota using low-temperature carbonization, power could be delivered to the Atomic Energy Commission plant at a cost of 2.57 mills/kw.hr., using strip-mined lignite at 8 cents/million B.t.u. If the selling price of the tar and light oil distillates were increased from 5 to 7 cents/gal., the cost of power would be reduced to 2.25 mills/kw.hr.

CARBON RAW MATERIAL FOR SYNTHETIC CHEMICAL MANUFACTURE

The manufacture of ammonia and other chemicals has been built around the use of coal or coke for synthesis gases, including carbon monoxide, carbon dioxide, and hydrogen. Low-cost natural gas has caused a trend from the use of coal as a raw material for these chemicals. The replacement of natural gas is favored by increasing gas prices and by the application of low-temperature-carbonization techniques, particularly as applied to low-cost solid fuels such as strip-mined lignite in the Dakotas.

SMOKELESS FUEL FOR HAND FIRING

At least one large installation (4) is using the low-temperature-carbonization process for the manufacture of smokeless fuel. Although the Disco process is operating on coking coal, it is believed that noncoking subbituminous coals and lignites could also be upgraded.

SEMICOKE

The electric furnace reduction of phosphatic and other ores requires the use of coke. The

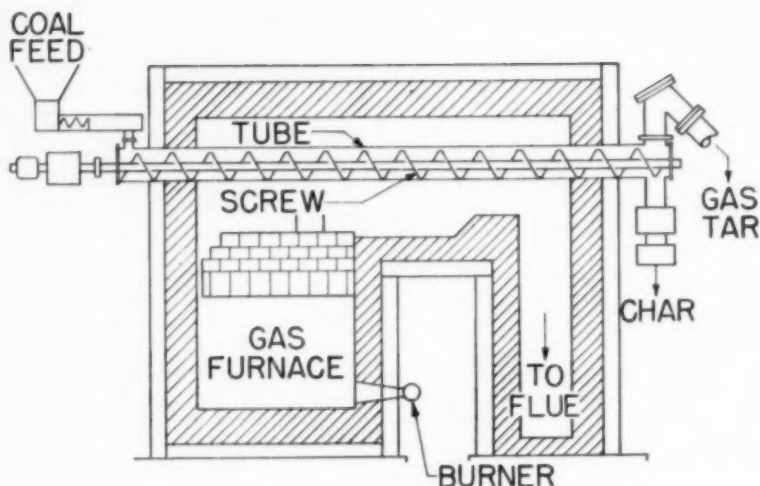


Fig. 4. Hayes process.

largest deposits of phosphate rock in the world are located in the Rocky Mountain area where there is only a limited amount of coking coal. Because of these factors it is believed that the low-temperature carbonization process has a place in this area for the manufacture of semicoke from subbituminous coal and lignite. In some instances additional processing of the low-temperature char may be required and the development of the auxiliary treatments appears to be favorable.

SUBSTITUTE FOR LOW-VOLATILE BITUMINOUS COAL FOR CHARGING COKE OVENS

In the manufacture of metallurgical coke the volatile matter of the coal used should range from 20 to 30% for maximum yield (9). Thus a coke oven operating in an area of high-volatile coal will supplement this coal with low-volatile coal transported from another area, or the coke oven can be supplied with a mixture of high volatile coal and char produced

from low-temperature carbonization of high-volatile coal (7).

RAW MATERIAL FOR METALLURGICAL COKE

In areas where coking coal is scarce, it would seem that low-temperature-carbonization processing of subbituminous coals and lignite could aid the development of a method for producing metallurgical coke from these noncoking coals. The development of a process for making a suitable metallurgical coke from the North Dakota lignite, which is the second largest solid fuel reserve in the United States, would be important to the steel industry in connection with the large deposits of iron ore in Minnesota. The development of a process for making suitable coke would create a major expansion of the steel industry on the shores of Lake Superior which would result in a shipment of iron and steel instead of iron ore from the western shore of Lake Superior.

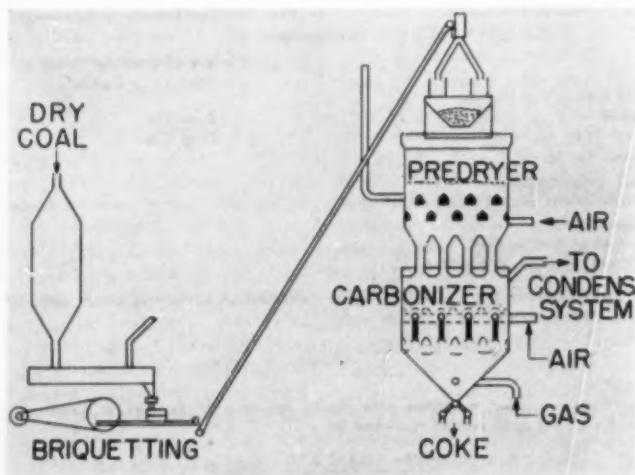


Fig. 5. Lurgi-Spülgas process.

CARBONIZATION OF AGRICULTURAL AND INDUSTRIAL WASTES

Use of low-temperature carbonization techniques for the destructive distillation of sawdust has already been demonstrated and there are indications that the process can be applied to the carbonization of wood chips, corncobs, sewerage sludge and similar agricultural and industrial waste materials.

ACTIVATED CARBON RAW MATERIAL

It has been demonstrated that the char produced by low-temperature carbonization is a much more reactive carbonaceous material than that produced at higher temperatures. Thus the production of activated carbon from low-temperature char should be an interesting possibility.

Summary

In the foregoing discussion the development of the techniques of the low-temperature-carbonization process has been emphasized. Several types of process and equipment have been described to transfer heat for the carbonization of coals at low temperatures in the range of 500° C. In this temperature range the use of refractories is not required and the processing equipment can be constructed with ordinary carbon steel which greatly reduces the cost of the installation. The use of fluidization and other devices has enabled a design for low-temperature carbonization to be successfully accomplished with low-cost equipment, with a minimum of operating labor and with a maximum utility of application to a number of fields other than the low-temperature carbonization of coal.

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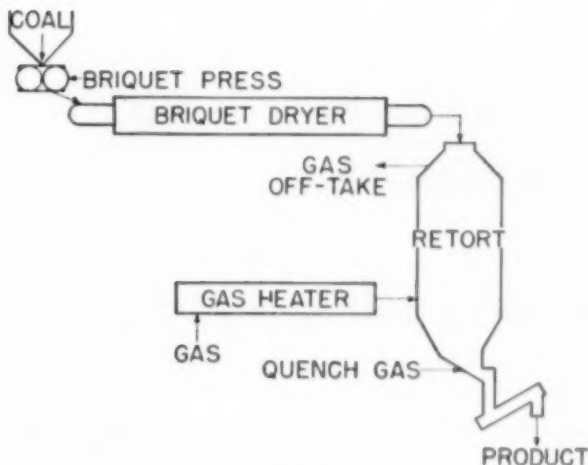


Fig. 6. National Fuels Corporation process.

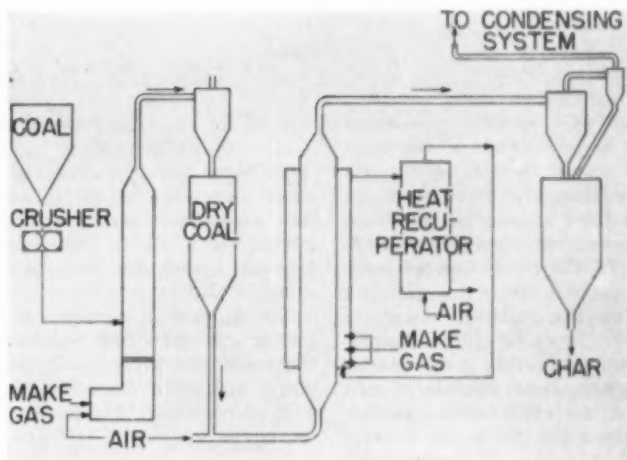


Fig. 7. Parry process—1952.

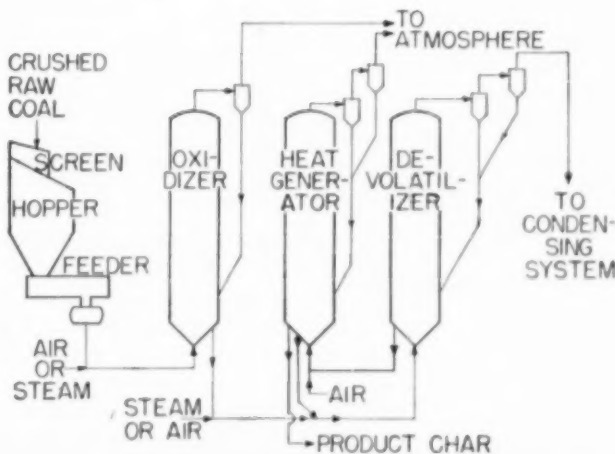


Fig. 8. Singh process.

The Batch Cooling of a Watermelon

R. W. G. Rhodes and R. L. Huntington

School of Chemical Engineering
University of Oklahoma, Norman, Okla.



No objection to fraternization could be observed.

A large percentage of the experiments which are performed in the chemical engineering unit-operations laboratories involve the steady flow of mass, heat or momentum rather than transient flow as found in batch processes. In casting about for an experiment illustrative of a batch operation, it was decided that a summer-time laboratory class might find an experiment connected with refrigeration to be of interest, especially one in which the experimental object could be eaten at the conclusion of the test period. A cork-lined cold

room maintained at 32° F. to 35° F. was available in our laboratories for the carrying out of the experiment selected, namely the batch cooling of a watermelon.

The differential cooling rate of the melon was calculated by considering the mass heat capacity of the several shells, as well as the core centered by each thermometer. The calculated cooling curve is presented in Figure 1.

Added interest was injected into the experiment by awarding an extra slice of melon to the student who estimated

most closely the time when a temperature of 40° F. would reach the center of the melon.

The value of such an experiment may be questioned by some staff members who may look upon it as being too far removed from plant operation or process design. Others, however, may consider it worth while from the standpoint of human interest and fraternization. To say the least, none of the students voiced any objections so far as could be heard or observed.

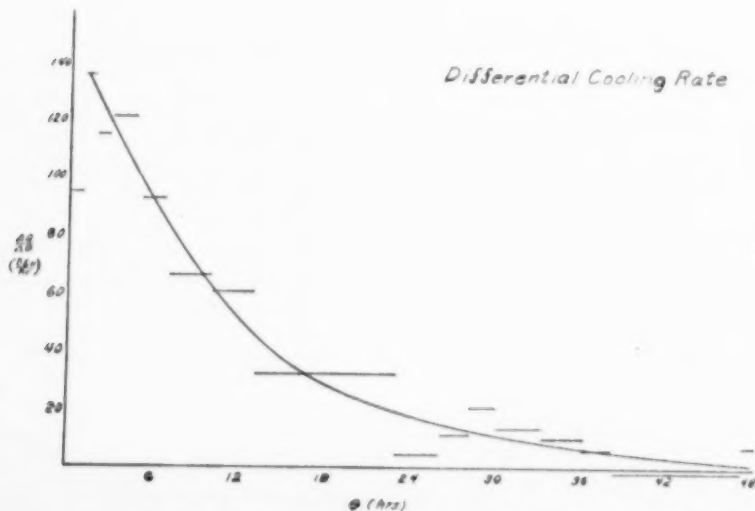


Fig. 1. Calculated cooling rate curve for the refrigeration of the melon.

Recovery of Manganese from Low-Grade Ores

Louis N. Allen, Jr.

Chemical Construction Corporation, New York

Approximately 2,000,000 tons of manganese ore are used annually in the steel-making industry in the United States. In 1951 local production in the U. S. was 120,000 tons of ore or 6% of consumption. The balance was imported mainly from India, Africa, and Brazil. The Government has been attempting to build up a stockpile but because of increased consumption, it is estimated that there remains on hand little more than a year's supply of manganese ore, an amount just enough to fill up the lines leading to the steel mills. In the event of war and the consequent cutting off of foreign supplies of manganese no vigorous start on accelerated domestic production could be expected. Of the 120,000 short tons of manganese ore produced in this country the majority comes from a single producer the Anaconda Copper Co., Butte, Mont., and this is merely a by-product of a rather extensive ore beneficiation. The balance comes from numerous small producers located in about ten states of which probably not more than

a dozen can be counted on for production of any appreciable quantity.

During World War II a fairly large-scale plant for hydrometallurgical beneficiation of low-grade manganese ores was in operation at Three Kids, Nev., but the operation is generally conceded to be only partly successful. Descriptions of the process have appeared in the literature (1) but the system will be described again since it will serve as a basis of comparison with the new process.

A slurry of manganese ore was reacted in slot-packed towers with sulfur dioxide gas. The MnO_2 reacted to form manganese sulfate and manganese dithionate. Thus



and



After separation of unreacted solids and countercurrent washing, the liquor was sent to evaporators. Some reduced ore was added to kill the acidity and minimize the dithionate

breakdown to sulfate and sulfur dioxide. After evaporation a mixed crystal of sulfate and dithionate was obtained. This was then roasted in a direct-fired kiln to regenerate sulfur dioxide and produce a manganese oxide product. Most of the trouble came in the roasting operation where rings were formed in the kiln.

Recently the Chemical Construction Corp., working with two other groups, developed an SO_2 process which had two new features, a high temperature autoclaving step and a sintering operation. Figure 1 shows the flow of this process.

In this new process low-grade manganese concentrates are chemically treated to make a high-grade manganese oxide product.

The process consists essentially in reacting the concentrates in slurry form with sulfur dioxide gas to convert MnO_2 to $MnSO_4$, heating the reacted slurry in an autoclave in the presence of oxygen to improve the extraction and eliminate side-reacting products, decanting the liquid which is essentially a solution of manganese sulfate, washing the tailings to recover contained soluble salts, evaporating the manganese sulfate solution, separating the manganese sulfate crystals and sintering to manganese oxide. Sulfur dioxide gas produced in the sintering is recycled.

The following study applies particularly to the treatment of 20.2% Mn concentrates which were obtained by beneficiating a typical core-drilling sample from Aitken County, Minn., in the Cuyuna range. A 303 long ton/day



Lou Allen, the author, was graduated from Stevens Institute of Technology as M.E. in 1931 and again as M.S. in 1933. After graduation he joined the American Cyanamid organization where he presently is chief chemical engineer of the Chemical Construction Corp. In 1945 he went to China as a technical consultant under Donald M. Nelson. Allen has taken an active part in the recent developments in the recovery of metals by the new Chemico technique of which the paper "Recovery of Manganese from Low Grade Ores" is a part.

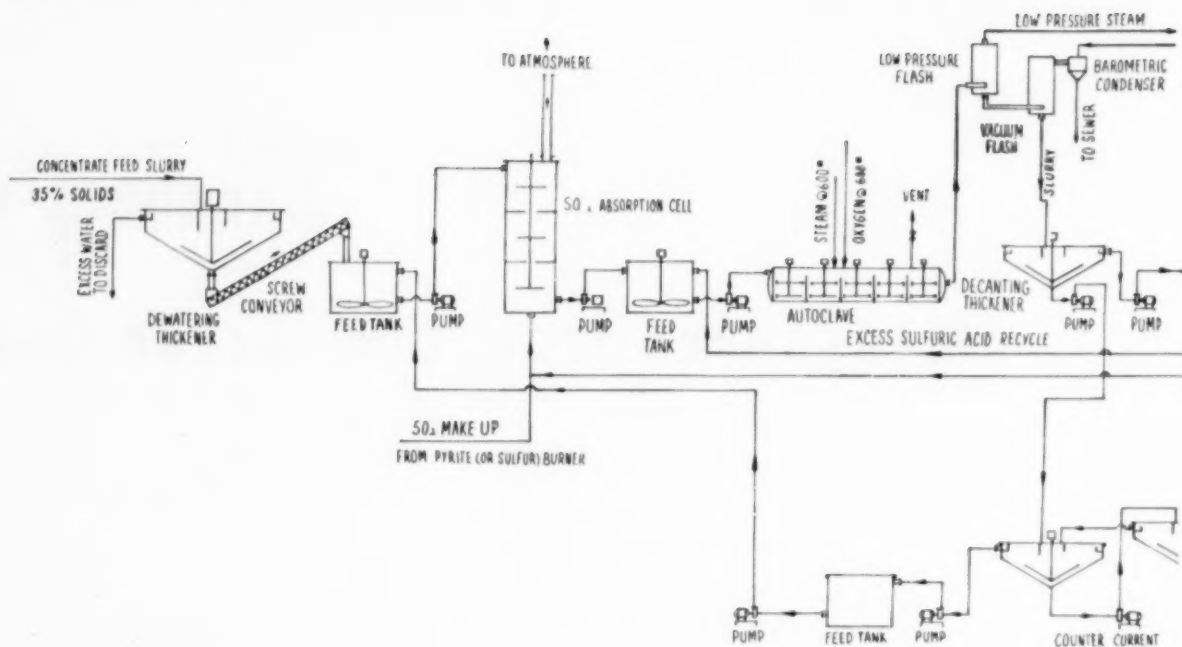


Fig. 1. Flow

Mn hydrometallurgical plant located near the ore body has been selected as the basis for this study.

The ore-concentrating plant is covered by a separate study. Preliminary tests indicate that a wet mechanical beneficiation process could be used to raise the grade from 4.6 to 20.2%. Wet grinding, included as part of the ore-concentrating plant, would reduce the concentrates to -48 mesh and the concentrates would be pumped as a 33% slurry to the plant. At the plant a thickener will be used to concentrate the slurry from approximately 35 to 75% by weight of solids. This 75% underflow will be removed from a thickener by means of a screw conveyor and will be added to the leach cycle.

The leaching will be accomplished in a number of vertical, cylindrical, agitated vessels operating in parallel. Horizontal internal baffles divide each tank into three superimposed compartments. Each compartment is agitated with a turbine-type propeller mounted on a common shaft. Incoming SO_2 gas is introduced under pressure below the lowest impeller and is broken up by the turbine into small bubbles which rise in the compartment, are re-collected by one of the baffles, and are introduced below the second impeller. The third or top compartment acts in a similar manner.

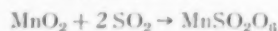
The manganese in the Cuyuna concentrates dealt with here is in the form

of the dioxide and the leaching may be essentially represented as:

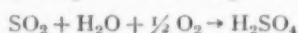


It should be noted that natural occurring MnO_2 is unreacted by dilute sulfuric acid and requires a reducing agent such as SO_2 to enter the crystalline structure which is usually represented as $\text{Mn}-\text{MnO}_4$, rather than $\text{Mn}-\text{O}_2$.

Some of the SO_2 may be absorbed as a thionate, thus:



and some of the oxygen associated with the weak SO_2 gas may be catalyzed by MnSO_4 to oxidize SO_2 , thus:



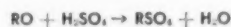
The slurry from SO_2 absorption is pumped under pressure to the oxidation step. The oxidation will be accomplished in autoclaves which will be horizontal, cylindrical tanks, divided into compartments by internal baffles. Each compartment will be agitated by a single impeller which will be introduced through the top of the tank, and steam will be introduced as required into each compartment to maintain proper elevated temperatures. Air under pressure is introduced under the agitator in each compartment to promote the oxidation of the SO_2 to SO_3 as not provided for by the presence of MnO_2 . Oxygen will be supplied as air, thus:



Furthermore SO_2 previously dissolved as sulfites or sulfurous acid will be oxidized



This free sulfuric acid will be partially used to transform soluble nonmanganese oxides to sulfates



Furthermore, aluminum, iron, and magnesium sulfates which are so produced are rendered relatively insoluble at the high temperatures. The iron in solution in relation to manganese is well below the commercial specification of 1 to 6 and in most cases is below 1 to 20.

The oxidation-slurry effluent under high temperature and pressure is flashed in two stages to a final temperature of 160° F. Steam generated in the first-flash stage is used as hereafter noted to further concentrate manganese sulfate solutions and from the second to heat wash waters for process.

The slurry thus cooled is then decanted to produce a relatively clear manganese sulfate solution and the underflow treated in a countercurrent-staged dilution washing system to recover the soluble manganese sulfate salts from it. Wash water from this system is added to the SO_2 leaching step as noted on the flow diagram.

Evaporation of the manganese sulfate solution will be accomplished in two stages. In the first stage, during which no solids will be removed but will pass on as magma, the liquor

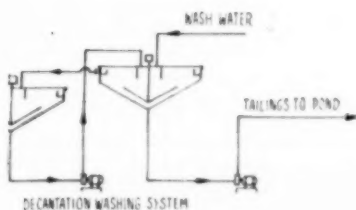
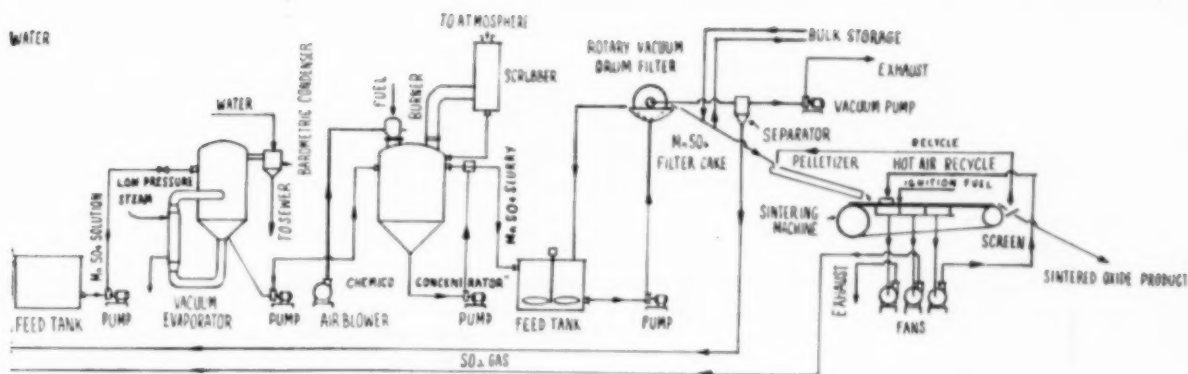


diagram.

from the decantation will be partially evaporated and some of the manganese sulfate will be precipitated into the magma as a monohydrate. The crystals will be as monohydrate rather than as hexahydrate since the temperature will be about 150° F. This evaporation will be accomplished under vacuum and the vapor removed via barometric condenser. Magma will be recirculated through a heat exchanger and heated by the first flash of the oxidation autoclave exit product. The first evaporator will be operating continuously. Manganese sulfate liquor will be added and magma withdrawn at constant rates.

The second effect will be operated at approximately 260° F. Evaporation is by means of injecting hot gases below the surface of the liquid, using the technique as defined in the Nordac patents which have been licensed by Chemical Construction Corp. By returning mother liquor after filtration of manganese sulfate, a magma density of approximately 40% solids by weight and a liquid phase of 60% H_2SO_4 will be maintained in this vessel. In the range of 40-70% and preferably 55-60% H_2SO_4 , manganese sulfate crystals will be grown to a size where they are readily filterable.

A portion of the magma is continuously recycled to a weir box and a portion, corresponding to the make, is withdrawn to a magma-holding tank which acts as a feed supply tank for

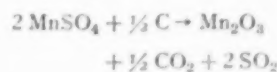


From 20% Mn concentrate to 60% Mn sintered product.

the vacuum filters. The filter cake which, after washing consists of 80% $MnSO_4$, 5% H_2SO_4 , and the balance water and other sulfate ingredients, is conveyed by a belt conveyor to a covered storage area.

Approximately one-week supply of sulfate is maintained at all times. The storage pile is reclaimed with a payload. Weighed batches of sulfate, powdered coal, and powdered recycled oxide are made up and then transported to a rotating drum where water is added and small spherical pellets are produced. These pellets are dumped

onto the grate of a Dwight Lloyd sintering machine which is divided into three compartments. In the first compartment hot air generated by drawing air through the bed of the third compartment to cool the sinter is passed through the layer of pellets whereupon they are dried. In the second compartment the pellets are ignited and a small portion of the carbon of the coal is used to reduce the manganese sulfate, thus:



The balance is burned to carbon dioxide and furnishes the heat to raise the bed to sintering temperature.

A good grade, hard porous sinter is formed which falls off the end of the machine in slabs, is rough-ground in a Knittle crusher, and is screened to furnish a $+1/4$ -in. hearth layer. The balance is ground to -50 mesh in a ball mill to furnish the recycled oxide. The make or production may be taken either as slabs, rough-ground, or screened product. The $+1/4$ -in. would probably be the best form of product. This is mechanically conveyed to a silo which fills railroad cars. The 7 to 8% SO_2 gas from the center compartment of the sintering machine is compressed to 6-lb. gauge and sent to the SO_2 absorption.

To make up losses, principally SO_2 lost in sintering and sulfur in tailings, pyrite must be burned to SO_2 and introduced into SO_2 absorption. It is assumed that this make-up will be supplied by burning pyrite in a fluidized bed burner. Air for combustion is compressed to about 9-lb. gauge to give 6-lb. gauge in the line to SO_2 absorption. A waste heat boiler preceded by hot gas cyclones recovers part of the sensible heat in the gas before it goes to SO_2 absorption.

Tailings are reslurried in cooling water effluent and pumped to a sludge pond.

It is estimated that to produce 303 long tons, Mn/24 hr. as sintered oxide, equivalent to 100,000 long tons/year, a plant would cost \$16 $\frac{1}{2}$ million. The direct operating cost summarized in Table 1 would amount to \$41.33/long ton Mn or 41.33 cents/unit.

If the concentrates could be delivered to the plant for 30 cents/unit and if amortization is taken on an accelerated basis at 17 $\frac{1}{2}$ %/year for 28.9 cents/unit, the total cost would be about \$1.00/unit. This is exclusive of any royalty, profit or development. The government agencies are currently allowing \$2.00 to \$2.30/unit for 40% Mn delivered to Deming, N. M., or Phillipsburg, Mont. On this basis it would seem that the process spells good business.

The piloting was done on bench scale. The analysis of the ore and concentrate is shown in Table 2.

The screen size was 100% - 48 mesh for early runs and 100% - 80 mesh for later runs. Leaching tests were run as follows:

The weighed ore sample was slurried with twice its weight of water and then placed in a flask fitted with an agitator, vented condenser, and gas-bubbler tube. A stream of air containing about 7% SO_2 was passed into the stirred slurry through the bubbler tube located just

Table 1.—Estimated Operating Cost/Long Ton Manganese

Operating labor—3.7 man-hr. @ \$1.65 ..	6.05
Supervision & plant overhead	2.35
Pyrite (45% S) 0.625 short tons @ \$8.00 ..	5.00
Coal—0.615 short tons @ \$11.00	6.76
Fuel gas—21.7 million B.t.u. @ \$0.28	6.10
Electricity—6.50 kw-hr. @ \$0.012	7.80
Water—18,000 gal. @ \$0.015	0.27
Repairs & maintenance	7.00
Total cost/long ton manganese	\$41.33

Table 2.—Analysis of Cuyuna Manganese Concentrate

Mn	20.2%	Loss on ignition	9.3%
Fe	22.9	Moisture	0.6
Ca	0.3		
Mg	0.1		
Al	3.9		
K	1.2		
S	0.1		
P	0.13		
SiO_2	19.6		

Table 3.—Manganese and Iron Extractions

Test No.	Mole Ratio S/Mn	After Leaching			After Autoclaving		
		pH	% Mn	% Fe	pH	% Mn	% Fe
8	1.15	2.8	....	...	...	89.1	2.4
10	1.24	2.5	72.5	2.3	3.8	89.8	6.6
12	1.25	2.9	78.6	0.5	1.1	97.6	3.7
16	1.26	2.0	....	...	2.5	98.1	10.4
20	1.22	1.1	80.8	2.1	0.9	97.5	6.1

under the moving agitator blade. Gases escaping at the surface passed out through the condenser, which removed some of the water vapor picked up in the flask. For most of the runs a slurry consisting of 800 g. of ore in 1,600 g. of water, was placed in a 3-l. flask. The gas flow rate for all runs was about 19 l./min. During leaching the temperature rose to a maximum of 45° F. The gas was bubbled through the slurry until the amount of sulfur dioxide absorbed was approximately 1.4 times the weight of manganese in the ore concentrate. This gave a final mole ratio of sulfur to manganese in the slurry of about 1.2.

The extraction of manganese from the concentrate during the leaching step, alone, was fairly constant, once experimental techniques were standardized. It ranged from 72 to 85%, based on the total recovery of manganese after leaching. It seemed that the addition of small amounts of sulfuric acid during leaching increased extraction, but the data were not conclusive. Extraction of iron during leaching varied from 0.5 to 5%. Low pH during leaching tended to increase iron extraction. Table 3 gives the results of several leaching tests and the subsequent autoclaving, which will be described later.

Autoclave oxidation tests were run as follows:

The leach liquor contained a large amount of dithionate sulfur which was converted by oxidation to sulfate ion. The oxidation was performed in a stirred autoclave at 450° F. under a total pressure of 600 lb./sq. in. gauge.

The one-gallon autoclave used was built of Type 316 stainless steel and was designed for a working pressure of 1,000 lb./sq.in. at 650° F. It was equipped with an externally driven propeller agitator and an open-gas burner for

applying heat. Provisions were made for charging the material to be treated and for injecting and venting gases during operation. The autoclave could be cooled by water upon completion of a run.

All the autoclave runs were made at 450° F. and a total pressure of 600 lb./sq.in. gauge. The only variations introduced were in the quantity and quality of oxygen used and time of autoclaving. One run was held at the above conditions for one-half hour; the rest were held for 2 hr. In earlier runs compressed air was used to raise the total pressure to 600 lb., once temperature had been reached. Later pure oxygen was used. Thus, partial pressures of oxygen over the liquid varied from about 38 to 192 lb./sq.in., allowing 408 lb./sq.in. gauge for the vapor pressure of water at 450° F.

With the -80 -mesh concentrate, the filtration rate of the final slurry after autoclaving, through Number 2 Whatman paper under 15 in. of Hg vacuum, was about 2 gal./sq.ft. of filter area/hr. In the experimental runs the cakes were washed in place on the filter, either with one volume or two-half volumes of water. It was observed that washing rates were higher than filtration rates. These washing procedures gave good recovery of soluble values from the residue.

Countercurrent washing with centrifugation of the slurry to produce a clear final overflow, but with cloudy intermediate overflows, seemed like a procedure which might prove adaptable for any large-scale processing of this concentrate. The final answer to this problem probably must be found during pilot operations with the process.

The clear liquor separated from the oxidized slurry after autoclaving must be evaporated to crystallize the manganese as manganous sulfate. For this purpose, a 20-gal. submerged-burner evaporator was constructed. It consisted essentially of a lead-lined kettle with a removable tap designed to accommodate a tunnel burner, two dip pipes for feeding and discharging the

kettle, a fume stack, and a thermocouple well. The kettle had a glass tube sight glass for observing the liquid level. All piping attached to the evaporator was of lead; the kettle, kettle top, and burner were lead-covered. The fume stack was of black iron stove pipe and led to a packed water-absorption tower. The burner had a simple cylindrical chamber lined with ceramic material, open at the lower end and fed with a combustible mixture of natural gas and air at the upper end. A high-potential electric spark gap for igniting the mixture was located at the point where the fuel entered the burner. In practice the lower end of the burner was submerged, after ignition, about 8 in. beneath the liquid surface in the kettle, and remained in that position supported by the kettle top. The hot combustion gases leaving the submerged end passed up through a draft tube surrounding the burner, and then out through the fume stack. The upward flow of gases through the draft tube served to circulate the liquor in the evaporator and helped to produce uniformly

small crystals. The burner had a capacity of 100,000 B.t.u.'s/hr.

It was not practicable to process liquor prepared by leaching and autoclaving because of the quantity needed for the evaporator. Therefore, 50 gal. of a synthetic feed liquor, as nearly like the process liquor as possible, was prepared.

The evaporator was charged with 20 gal. of 60% H_2SO_4 solution and brought up to temperature. The feed liquor was then run in at a rate which maintained a constant liquid level in the kettle. As crystals formed, they were removed through the discharge pipe, along with some mother liquor. The crystals were filtered on a vacuum filter and the mother liquor returned to the kettle. The entire 50 gal. of synthetic feed was processed in this manner, yielding about 150 lb. of moist

Table 4.—Sintering Tests

Test No.	19	18	16
Charge—			
MnSO ₄ parts by weight....	40	50	60
Returned			
sinter parts by weight	60	50	40
Coal parts by weight	12	12	12
Product—			
Sulfur % avg.	0.38	1.70	..
Sulfur % fused vitreous part ..	..	0.27	..
sulfur % fused nonvitreous			
part .....	..	1.53	..

crystals. These crystals had an average particle diameter of about 0.01 in. and were dull orange in color.

During evaporation the liquid temperature in the kettle was held at about 260° F., the equilibrium boiling point of 50% H_2SO_4 solution. The crystals after filtration contained about 13% of their weight of sulfuric acid.

Sintering tests were made with batches containing about 10 lb. of mixtures of manganese sulfate, returned sinter, and coal. A tabulation of the composition of the charges, the operating conditions, and the results are shown in Table 4.

The conclusion based on these results is that satisfactory sinter can be obtained from manganese sulfate, and the quality of the sinter will depend on the variables that affect any sintering operation, namely, the quantities of sulfur and fuel in the charge. These quantities can be fixed by selecting the amounts of returned sinter and fuel added to the manganese sulfate.

It was shown that fairly satisfactory charges can be obtained by simply mixing the ingredients. This implies that the over-all sintering process might be made cheaper by avoiding the more expensive methods of extrusion or pelletization to agglomerate the fine materials.

Acknowledgment

The bench-scale tests, reported here, Institute. All work was done under an agreement with Chemetals Corp., exclusive licensee of the process. Acknowledgment is hereby given to the people in Battelle, Chemetals and Chemical Construction, who assisted in preparing this article and to the American Cyanamid Co., parent organization, for permission to publish it.

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Presented at A.I.Ch.E. Biloxi meeting.



Courtesy Battelle Memorial Institute

Oxidation tests were run in this 1-gal. autoclave.

A Scanning Device for Determining the Size Distribution of Spray Droplet Images

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Many research studies in chemical engineering require a particle-size analysis of one kind or another. Many methods have been devised for the analysis of particulate materials in the solid state. These methods range from simple screening operations, sedimentation procedures, and air elutriation, to tedious manual counting of particles viewed through a microscope.

In the studies of atomization, however, the above-mentioned methods are not usually applicable and the problem of determining the drop-size distribution of liquid spray droplets is generally a difficult and tedious analytical procedure. Because reasonable accuracy in size-dis-

tribution analyses requires the counting of many thousands of drops, recourse to manual-counting methods will be a great hindrance to the progress of atomization studies.

Review of Previous Work

Attention has been given by many workers to the problem of determining the drop-size distribution of sprays. In practically all instances distribution data must be obtained from spray samples obtained by some sampling procedure. These samples may either be the actual droplets collected in an immiscible solvent, for example, or they may be sec-

ondary evidence of the existence of the drops such as the holes produced in magnesium oxide coatings, or tracks left on soot-coated slides. In any case the size distribution usually must be determined by manually counting and classifying the drops or the evidence of drops. Generally this is facilitated by making enlarged photographs of the drop samples, and counting and classifying the drop images.

Methods for obtaining the average drop size of sprays without collecting drop samples have been studied (1, 6, 7), but such methods usually do not give distribution data.

Ingenious time-saving techniques have been proposed and used to speed up the counting and classifying involved in drop-size distribution determinations. These techniques have ranged from simple measuring and recording aids used by a human operator in manual counting, to elaborate automatic counting and classifying techniques in which human judgment as to size class is not required. Thus, Rupe (5) reported the development of an automatic counter in which drop images on a photographic negative were counted by a modified scanning procedure. The method consisted of optically projecting and focusing the photographic drop images mounted on a rotating drum on a double triangular array of six specially mounted photomultiplier tubes spaced according to the desired size class. Drop images falling between the inner and outer triangles are counted and drops greater than the outer triangle or less than the

An instrument is described which utilizes a scanning technique to count and classify spray droplet images on photographic negatives. These negatives mounted on a rotating drum are projected by an optical system and focused at the plane of a mask containing a small aperture and located directly in front of a photomultiplier tube. As the droplet images rotate past this aperture they are simultaneously advanced a small distance each revolution by the rotating drum. In this manner the phototube receives through the aperture a series of light pulses whose durations correspond to the lengths of the chords created whenever a drop image passes across the aperture. These light pulses of various time durations are converted into electrical pulses and fed into electronic sorter-counter circuits which classify the chords into fifteen size classes. A statistical treatment of this chord distribution is then made to give drop-size distribution. Tables of coefficients have been computed to permit rapid conversion of the chord distribution to drop-size distribution. The statistical theory on which these coefficients are based is presented. Results of tests on actual spray samples and on special test negatives demonstrated that the device will rapidly count and classify drops with acceptable accuracy. The scanning rate can be as high as 10,000 drops in 15 min. at maximum drum speed. Advantages of the instrument are that it removes the human element from the counting process, scans all drops in a single complete travel of the drum, simultaneously counts and classifies drops into fifteen size classes or less, and it counts much faster with greater accuracy than a human operator. Its principal limitation is that it is restricted to the analysis of transparent images on photographic negatives, which requires the sampling of sprays by the collection of droplets in cells on greased or soot-coated slides and photographing them.

Mr. Adler is associated with the Eastman Kodak Co., Rochester, N. Y., and Mr. Mark with Southern Illinois University, Carbondale, Ill.

inner are not counted. This method requires a scanning operation for each size class, and does not ensure the counting of every drop on the negative.

A scanning technique reported by Pigford (4) requires opaque drop images printed on photographic film for its operation. The drop images mounted on a rotating and advancing drum are made to interrupt a parallel light beam of rectangular cross section. Whenever the beam is totally interrupted, a count is registered. A statistical treatment of the count data is made to give the drop-size distribution. A separate scanning operation is required for each size class.

A recent patent by Hillier (2) describes a scanning procedure utilizing a moving light spot.

Theoretical Basis of Counter

The counter described in this paper is based on a scanning principle in which, effectively, a pin-point beam of light is made to pass in closely spaced parallel paths across transparent drop images. The passage of the light spot across the image, in effect, draws a chord across the circle. During passage of the light spot across the drop image light falls on a phototube and generates an electrical pulse whose time duration is proportional to the length of the chord. As the light spot passes successively across a given drop image, chords and hence light pulses of various lengths will be generated. (See Figures 1 and 5.) It is apparent that the light beam will cross many drops before it again returns, slightly displaced, to the given drop. (Figure 2 shows a typical negative of droplet images.) Therefore, light pulses of random time lengths will be continually generated so that the phototube will not know which drop is contributing a chord at a given time. Thus, the mathematical or statistical problem on which the counter and the accompanying calculations are based can be stated as follows:

STATEMENT OF PROBLEM

Given a distribution of chords obtained from the pin-point scanning of a randomly placed collection of circles, the problem is how the size distribution of the circles can be calculated from the chord distribution. The distributions in each case are grouped frequency distributions.

A brief summary of the statistical analysis and basic assumptions involved in a heuristic treatment of the above problem are outlined below.

Fig. 1. Geometry of the scanning process. (Bars over alpha, beta, and epsilon are equivalent to primes over same symbols in text.)

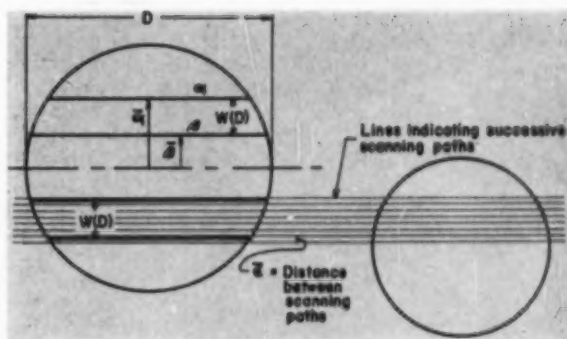


Fig. 2. Typical negative of droplet images used on counter.

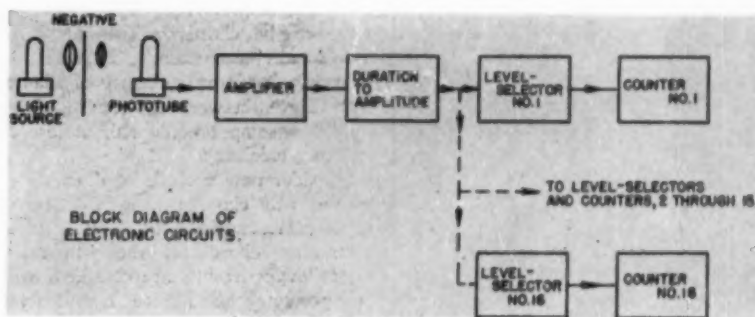


Fig. 3.

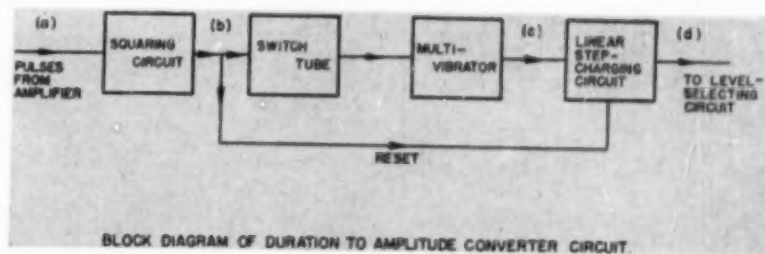


Fig. 4.

Table 1

i/k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00000														
2	-.39721	.46574													
3	-.09003	-.27973	.34983												
4	-.03327	-.05559	-.23549	.29200											
5	-.00713	-.02492	-.04481	-.20749	.25578										
6	-.00376	-.00335	-.02455	-.03867	-.18760	.23038									
7	-.00025	-.00386	-.00206	-.02272	-.03456	-.17253	.21130								
8	-.00067	-.00055	-.00398	-.00138	-.00098	-.03154	-.16059	.19429							
9	-.00019	-.00101	-.00090	-.00396	-.00098	-.02000	-.02921	-.15083	.18409						
10	-.00023	-.00051	-.00120	-.00108	-.00390	-.00071	-.01896	-.02733	-.14266	.17391					
11	-.00014	-.00044	-.00069	-.00130	-.00118	-.00381	-.00053	-.01806	-.02578	-.13568	.16525				
12	-.00011	-.00031	-.00058	-.00079	-.00135	-.00123	-.00371	-.01727	-.01806	-.12964	-.15777	.16525			
13	-.00009	-.00025	-.00042	-.00066	-.00085	-.00137	-.00126	-.00361	-.00330	-.01658	-.12434	-.15122	.15122		
14	-.00007	-.00020	-.00034	-.00049	-.00071	-.00088	-.00137	-.00127	-.00351	-.00235	-.01597	-.11964	-.14542	.14542	
15	-.00006	-.00016	-.00027	-.00040	-.00054	-.00074	-.00090	-.00137	-.00126	-.00342	-.00017	-.11544	-.14542	-.11544	.14024

STATISTICAL TREATMENT OF CHORD DISTRIBUTION DATA

The geometry of the scanning process is illustrated in Figure 1. Here the circles represent enlarged drop images and the horizontal, parallel lines represent scanning paths of the pin-point beam of light.

Let ϵ' be the distance between adjacent scanning paths. The problem is to determine the number of chords with lengths between α and β , where $\alpha < \beta \leq D$, which will result from scanning a circle of diameter D . Such chords will lie in two identical bands each having width $W(D)$ where

$$W(D) = \alpha' - \beta' \quad (1)$$

$$\alpha' = \frac{1}{2} \sqrt{D^2 - \alpha^2} \quad (2)$$

and

$$\beta' = \frac{1}{2} \sqrt{D^2 - \beta^2} \quad (3)$$

In other words, chords whose lengths are between α and β will have a distance between α' and β' from the center of the circle.

It can be shown that the expected number of chords to be obtained from each band will be given by $W(D)/\epsilon'$ a result which is intuitively clear. Hence, from a circle of diameter D the expected number of chords with lengths between α and β will be $2W(D)/\epsilon'$.

Suppose now that the circles are classified into n size classes such that the i -th class consists of circles with diameters between a_{i-1} and a_i ($i=0,1,2,\dots,n$ and $a_0=0$). For convenience the chords will be classified into similar size classes; i.e., the i -th class of chords will consist of chords with lengths between a_{i-1} and a_i . This simplifies computations without loss in counting efficiency.

Consider now a circle of diameter D in the i -th class, i.e., $a_{i-1} \leq D < a_i$. If $W(D)$ is the width of a band containing chords of the j -th class, the following results are obtained from the geometry of Figure 1 and from Equations (1), (2), and (3) taking $\alpha = a_{j-1}$, $\beta = a_j$:

$$W(D) = \frac{1}{2} \sqrt{D^2 - a_{j-1}^2} - \frac{1}{2} \sqrt{D^2 - a_j^2} \quad \text{for } i > j \quad (4)$$

$$W(D) = \frac{1}{2} \sqrt{D^2 - a_{j-1}^2} \quad \text{for } i = j \quad (5)$$

$$W(D) = 0 \quad \text{for } i < j \quad (6)$$

Table 2

i/k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00000														
2	1.15777	.021691													
3	1.16588	.029516	.12238												
4	1.16698	.029825	.17784	.08526											
5	1.16703	.029897	.17985	.12831	.06542										
6	1.16705	.029898	.18045	.12981	.10062	.05307									
7	1.16705	.029900	.18045	.13032	.10181	.08284	.04465								
8	"	"	.18047	.13033	.10226	.08383	.07044	.03853							
9	"	"	"	.13034	.10228	.08424	.07129	.06126	.03389						
10	"	"	"	"	"	"	.07165	.06203	.05424	.03024					
11	"	"	"	"	"	"	.07165	.06235	.05490	.04865	.02731				
12	"	"	"	"	"	"	.07166	.06235	.05520	.04925	.04411	.02489			
13	"	"	"	"	"	"	"	.06237	.05520	.04953	.04466	.04035	.02287		
14	"	"	"	"	"	"	"	"	.05521	.04953	.04491	.03718	.03718	.02115	
15	"	"	"	"	"	"	"	"	.05522	"	"	.04109	.03764	.03447	.01967

The computation of the number of chords in the j -th class contributed by circles of the i -th class requires an assumption concerning the distribution of circles within a size class. The simplest practical assumption is that the circles are uniformly distributed within each size class. On this assumption the density of circles in the i -th size class is $N_i/(a_i - a_{i-1})$ where N_i is the number of circles in the i -th class. In other words the number of circles of the i -th class with diameters in the range $(D, D + dD)$ is $N_i dD/(a_i - a_{i-1})$.

Now let $C(i, j)$ be the expected number of chords of the j -th class to be obtained from circles of the i -th class. Since a circle of diameter D contributes $2W(D)/\epsilon'$ chords, one can write

$$C(i, j) = \int_{a_{i-1}}^{a_i} \frac{2W(D)N_i dD}{\epsilon'(a_i - a_{i-1})} \quad (7)$$

The integration in Equation (7) involves the function $f(x, y)$ defined as follows:

$$f(x, y) = x \sqrt{x^2 - y^2} - y^2 \log(x + \sqrt{x^2 - y^2}) \quad (8)$$

Substitution of the formulas for $W(D)$ given in Equations (4), (5), and (6) into Equation (7) then yields the following after the integration is performed:

For $i > j$:

$$C(i, j) = \frac{N_i}{2\epsilon'(a_i - a_{i-1})} \{ f(a_i, a_{j-1}) - f(a_{i-1}, a_{j-1}) - f(a_i, a_j) + f(a_{i-1}, a_j) \} \quad (9)$$

For $i = j$:

$$C(i, j) = C(i, i) = \frac{N_i}{2\epsilon'(a_i - a_{i-1})} \{ f(a_i, a_{i-1}) - f(a_{i-1}, a_{i-1}) \} \quad (10)$$

For $i < j$:

$$C(i, j) = 0 \quad (11)$$

Matters can now be simplified further by assuming that the size classes are of equal width; i.e.,

$$a_1 - a_0 = a_2 - a_1 = \dots = a_n - a_{n-1}$$

By dividing each a_i by the common width of a class, the a 's may be written as integers; i.e., $a_k = k$, ($k = 0, 1, 2, \dots, n$) and the circles may range in diameter from 0 to n . The possibility that some circle size classes may be empty is not precluded. N_i is now defined as the number of circles with

diameters between $i - 1$ and i and the value of ϵ' is now expressed as a fraction of the class width and will be designated as ϵ .

With this adjustment of units, Equations (9), (10), and (11) may be written as

$$C(i, j) = \frac{N_i}{2\epsilon} a_{ij} \quad (12)$$

where the a_{ij} are given by

$$a_{ij} = \begin{cases} f(i, j - 1) - f(i - 1, j - 1) - f(i, j) + f(i - 1, j), & i > j \\ f(i, i - 1) - f(i - 1, i - 1), & i = j \\ 0, & i < j \end{cases} \quad (13)$$

$$a_{ij} = a_{ji} = \begin{cases} f(i, i - 1) - f(i - 1, i - 1), & i = j \\ 0, & i < j \end{cases} \quad (14)$$

$$a_{ij} = 0 \quad i < j \quad (15)$$

Letting C_j be the total number of chords of the j -th class contributed by all circles, Equation (16) can be written thus:

$$C_j = \sum_{i=1}^n C(i, j), \quad (j = 1, 2, \dots, n) \quad (16)$$

From (12),

$$\sum_{i=1}^n a_{ij} N_i = 2\epsilon C_j \quad (17)$$

and using (15), it follows that

$$\sum_{i=j}^n a_{ij} N_i = 2\epsilon C_j \quad (18)$$

It is instructive to write out Equations (18) in detail. Thus

$$\begin{aligned} a_{11}N_1 + a_{21}N_2 + a_{31}N_3 + \dots + a_{n-1,1}N_{n-1} + a_{n,1}N_n &= 2\epsilon C_1 \\ a_{22}N_2 + a_{32}N_3 + \dots + a_{n-1,2}N_{n-1} + a_{n,2}N_n &= 2\epsilon C_2 \\ a_{33}N_3 + \dots + a_{n-1,3}N_{n-1} + a_{n,3}N_n &= 2\epsilon C_3 \\ \dots &\dots \\ a_{n-1,n-1}N_{n-1} + a_{n,n-1}N_n &= 2\epsilon C_{n-1} \\ a_{n,n}N_n &= 2\epsilon C_n \end{aligned}$$

This system of simultaneous equations in triangular array consists of n equations in n unknowns since the a_{ij} are known by computation, ϵ is determined by the rate of scanning (see Table 4) and the width of a size class and the C_j are the chord counts furnished by the counter. The system can then be solved for the N_i . The last equation furnishes N_n at once and by working up through the equations N_{n-1} , N_{n-2} , \dots , N_2 , N_1 in that order can be determined. Values of the N_i thus obtained are experimental values or estimates of the actual N_i .

A convenient form for the solution of Equations (19) may be written as follows:

$$N_k = 2\epsilon \sum_{i=k}^n b_{ik} C_i \quad (20)$$

where the b 's are related to the a 's by the relations

$$b_{kk} = 1/a_{kk} \quad (21)$$

and

$$b_{jk} = -b_{kk} \sum_{i=k+1}^j a_{ik} b_{ik}, \quad j > k \quad (22)$$

Values of b_{jk} for j and k ranging to $n = 15$ were computed by the University of Wisconsin Numerical Analysis Laboratory and are given in Table 1.

An approximate analysis of the statistical errors can be made on the assumption that the errors are uncorrelated. The expression obtained for the standard error or standard deviation is as follows:

$$\sigma(N_k^*) = \frac{\epsilon}{\sqrt{3}} \sqrt{15 \sum_{i=k}^n d_{ik} N_i} \quad (23)$$

where $\sigma(N_k^*)$ is the standard deviation of N_k^* , the experimental value of N_k obtained from Equations (18) or (20), and the d_{ik} are given by

$$d_{ik} = \sum_{j=k}^i b_{jk}^2 \quad (24)$$

The probable error of N_k^* is 0.675σ

(N_k^*). Values of d_{ik} as computed by the same laboratory are tabulated in Table 2. One may use N_i^* in place of N_i in the right side of Equation (23) in attempting to approximate $\sigma(N_k^*)$.

It is evident from the above expression for σ that the accuracy of the method is dependent on ϵ , the distance between scanning paths. This was demonstrated prior to the construction of the scanning drum and the electronic circuits by an experiment in which circles of various sizes were drawn on graph paper. Chord distributions were

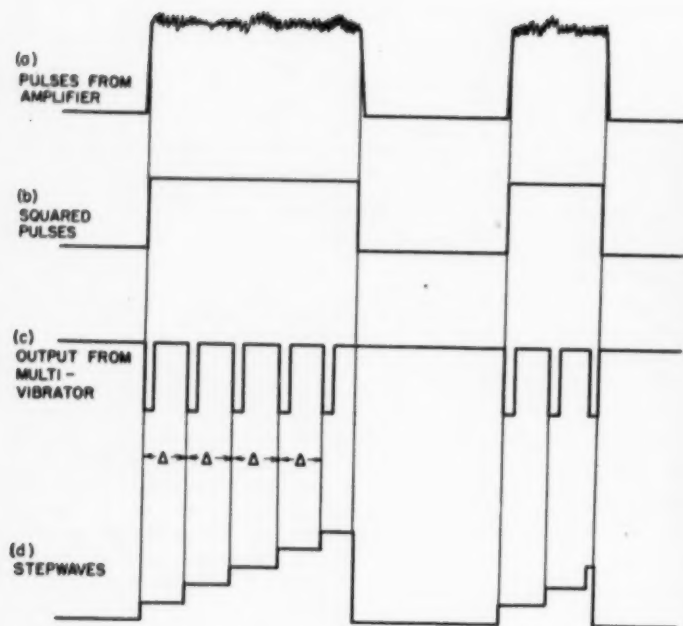


Fig. 5. Waveforms from circuits shown in Fig. 4.

then determined by manual counting for various chord spacings; i.e., for various values of ϵ . Results tabulated in Table 3 show the importance of maintaining ϵ small in the scanning process. More important, the results of these tests justified further development of the proposed method.

Electronic Circuits of Sorter Counter

The light pulses which are generated by the droplet images cutting the light beam must be classified according to length if calculation of drop-size distribution by the preceding theory is to be accomplished. An electronic method of counting and classifying was obviously necessary to meet the requirements of speed and accuracy. Electronic counting methods have been used by previous investigators (2, 5) but the method outlined here has not been found in the literature.

Description of Electronic Circuits

Referring to the block diagram of Figure 3—the moving drop images on the negatives generate light pulses having time durations directly proportional to the chord lengths of the images. These pulses of light strike the phototube where they are converted into electrical pulses bearing a one-to-one correspondence in time duration. These electrical pulses are next ampli-

fied sufficiently to operate reliably the circuits which follow.

These electrical pulses must be sorted and classified by actuating circuits which will discriminate between pulses of various time durations. The method selected to do this was the conversion of electrical pulses of various time durations into new electrical signals of proportional voltage amplitude because it is easier to measure a voltage amplitude by electronic means. This is accomplished by the circuits in the block labeled "duration to amplitude."

This new variable amplitude signal is then fed to sixteen parallel level-selecting circuits. These circuits operate when a signal of some specified amplitude is impressed. In this device each progressively higher number level-selecting circuit is set to operate at a voltage level a fixed amount higher than the one preceding it. This means that the longer the chord, the higher the voltage amplitude and the higher the number of the level-selecting circuit actuated. Thus, if the pulse due to a particular chord actuates the first five level-selecting circuits and a following pulse actuates ten, the second chord within a class size is twice as long as the first. A means is thus established for sorting the chords with respect to length. With sixteen level-selecting circuits it is possible to sort and classify the chord lengths into sixteen distinct size ranges.

The remaining task is to count the number of chords in each size range. This is accomplished by following each level-selecting cir-

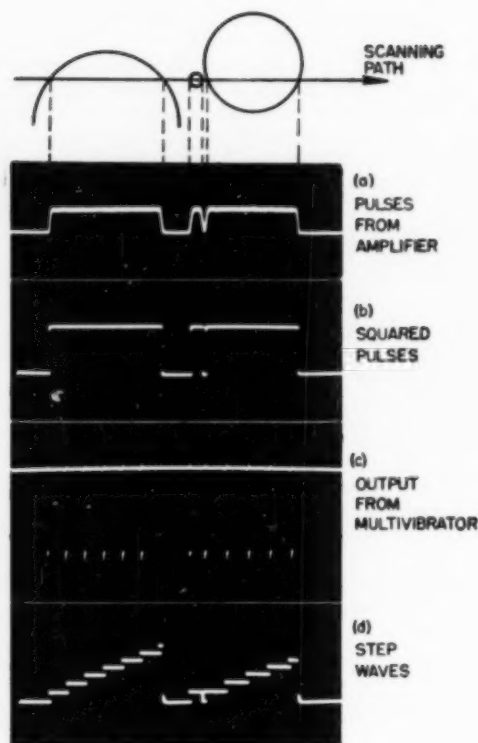


Fig. 6. Photographs of waveforms as seen on oscilloscope.

cuit with a counter (Fig. 3). Each counter consists of an electronic scaling circuit followed by an electromechanical register. As each level-selecting circuit is actuated it passes a signal on to its corresponding counter causing it to advance one count.

It is to be noted that regardless of the chord length, the first counter will receive a count, and therefore, count the total number of chords. The second counter, however, will receive a count only if a chord is longer than the first size range; the third counter will receive a count only if a chord is longer than the second size range, etc. As a result the number of chords in the first size range is obtained by subtracting the count of the second counter from that of the first. In general, the number of chords in the n th size range is obtained by subtracting the count of the $(n+1)$ counter from the n th counter.*

Conversion from Duration to Amplitude

A more detailed description of the method of converting from electrical pulse duration to voltage amplitude can be given with reference to Figure 4. The block in Figure 3 labeled "duration to amplitude" has been expanded in Figure 4, and sketches of idealized voltage waveforms in this circuit are shown in Fig-

* The equipment has since been modified so that each counter records only the chords in its corresponding size range.

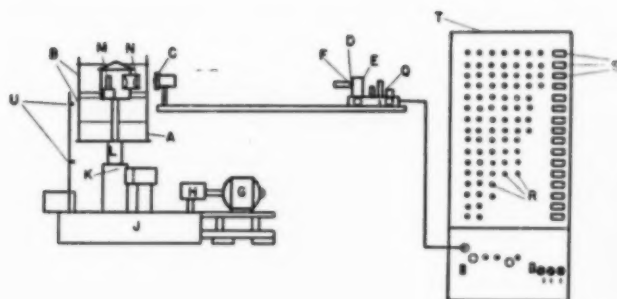


Fig. 7. Diagrammatic sketch of arrangement of elements of scanning drum and electronic system. ▲

Fig. 8. Photograph of counter and scanning drum. ►



ure 5. The corresponding actual wave forms as observed on a cathode-ray-oscilloscope screen are shown in Figure 6.

Pulses from the phototube and amplifier, Figure 5 (a), are fed in at (a) Figure 4. They are first squared and clipped so as to standardize their amplitude. The output of the squaring circuit at (b) in Figure 4 is shown in Figure 5 (b). This squared pulse is used to operate a switch tube which in turn allows a multivibrator to operate for a time equal to the duration of the pulse. The output of the multivibrator is shown in Figure 5 (c). The period Δ of the multivibrator determines the size range. The output of the multivibrator is used to operate a "step charging circuit" which produces the step wave form of Figure 5 (d). Each step of this wave form corresponds to one cycle of multivibrator operation and also to one size range. We now have signal that has a voltage amplitude proportional to the time duration of the phototube pulse and hence also proportional to chord length. The reset signal in Figure 4 is used to reset the step-charging circuit to zero reference level at the end of each pulse so as to be ready for the next pulse.

The step wave is impressed on the sixteen level-selecting circuits to cause them to operate and pass on counts to the counters in the manner previously described.

Photographs of these wave forms as seen on the screen of a cathode-ray oscilloscope are shown in Figure 6. The diagram at the top of the figure illustrates how chords of three different sizes contribute pulses of different lengths which become step waves as shown at the bottom of the figure. The largest chord will fall in the seventh size class, the smallest in the first, and the third chord in the fifth size class.

Further details on the electrical circuits have been reported by Parent and Schumann (3).

Description of Instrument and Its Operation

A diagrammatic sketch of the scanning drum and electronic-sorter-counter is shown in Figure 7. Figure 8 is a photograph of the drum and counter. With reference to Figure 7 the negatives *B* are mounted on the periphery of the drum *A*, whose diameter is one foot. This drum, driven by a synchronous motor *G*, can be rotated at different speeds, depending on the gear ratios used in the transmission system *J*. During rotation the drum is simultaneously advanced up or down by a nut on the drum shaft *L* driven at a speed slightly less than the drum speed. This is similar to the procedure used by Rupe (5). Figure 9 shows details of the transmission system. The amount of axial movement of the drum for each revolution can also be varied by changing the gear ratios in the transmission system. Limit switches *U* automatically stop the axial travel of the drum. Table 4 gives a few combinations of drum speed or axial rate of advance for various film magnifications and multivibrator frequencies. These various combinations permit covering different overall drop-size ranges by changing the size class. Thus, if the drops collected fall in a size class greater than the fifteenth, when each size class covers a $30\text{-}\mu$ interval, then shifting to a multivibrator frequency of 2,500 cycles/sec. will double the size class to $60\text{-}\mu$, and thereby include all drops in fifteen size classes.

The actual scanning procedure consists of projecting the drop images by means of an optical system, *M, N*, and *C*, and focusing the projected image on a plane at *D*, wherein lies a metal foil *F* placed in front of a photomultiplier tube *E*. In the center of this foil is a small aperture having a diameter of between 50 and $100\text{-}\mu$. This aperture corresponds to the concept of a pinpoint beam of light which was visualized in the development of the

theory. As the drop image passes across the foil, light passes through the aperture as a small beam and illuminates the phototube causing an electrical pulse to pass to the amplifier *Q* and thence into the sorter-counter, *T*. The length of the pulse is proportional to the length of the chord of the circle scanned. Typical pulses as received by the counter are shown in Figures 5a and 6a. The manner in which these pulses are modified, sorted, and counted has already been described.

As noted above, the data obtained from the counter consists of cumulative chord counts from the mechanical registers *S* and neon lights *R*. A set of subtractions gives the chord distribution which is then treated according to the procedure described under theory. The actual multiplication—summation process required for each size class was eventually performed on the 602A IBM calculating punch operated by the University Numerical Analysis Laboratory. (Desk calculators were also used effectively.) By means of the IBM machines several sets of scanning data can be calculated simultaneously. The coefficients in Table 1 were punched on a set of master cards and the chord counts for each run were punched in new cards and collated with the master cards.

The total scanning time varies according to the drum speed and the rate of axial advance of the drum. Thus, ten 5×7 negatives can be scanned with required accuracy in from $7\frac{1}{2}$ to 15 min. If each negative contains an average of 1000 drop images, then 10,000 drops could be scanned in this period. The time required to convert the chord count data to drop-size-distribution data requires about 15 min. with a desk calculator. With the IBM machines the computation time is much shorter.

Results of Performance Tests

EVALUATION WITH TEST STRIPS

In order to study the performance characteristics of the counter, several special tests were devised. The first controlled test procedure consisted of scanning a series of transparent slits of

Table A.—Results of Scanning Test Strips

Counter No.	Number of counts		Counter No.	Number of counts	
	Calc.	Obs.		Calc.	Obs.
1	115.7	117	8	132	132
2	115.7	117	9	232	232
3	107.7	107	10	199	199
4	99.5	99	11	165.5	166
5	182	183	12	132	132
6	165.7	165	13	397	399
7	149	149	14	265	267
			15	265	265

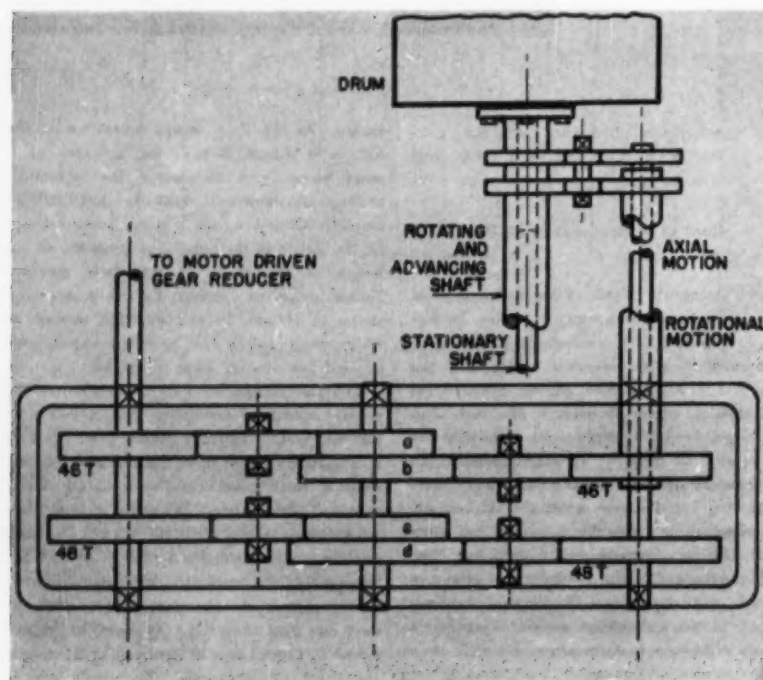


Fig. 9. Gear arrangement in drum transmission system.

uniform widths corresponding to the several size classes. From a knowledge of the axial speed of the drum and the width and length of each slit, the number of counts to be expected in each counter could be calculated prior to scanning. This calculated count was then compared with the count obtained from the instrument. A comparison of calculated values vs. the counter reading for a typical test is given in Table A.

The above results were duplicated many times on many different occasions, which served to prove the reliability of the circuits.

It is evident from the results of scanning the test strips that the counter should be expected to furnish reliable chord counts, provided negatives without serious imperfections and with uniform black backgrounds are used. The test strips were generally used as a standard to check the operation of the counter before and after its use on actual droplet images.

RESULTS WITH ACTUAL DROPLET SAMPLES

Results of tests for typical spray-droplet samples are shown in Figures 10 through 14. Figure 10 shows the frequency curves and a cumulative plot for an actual sample of spray droplets. It is evident that the scanning device tends to distribute the drops in adjacent size classes differently from the manual count. The good agreement obtained for the cumulative plot shows that the total number of drops determined by the counter agrees well with that for the manual count, and hence the differences in the frequency plots are essentially the difference in discrimination between a human counter and the electronic counter; i.e., the human counter does not discriminate as critically or as consistently among borderline drops.

Table 3.—Results of Experiments to Test Statistical Theory

$\epsilon = 0.5$						$\epsilon = 0.2$				$\epsilon = 0.1$				
	Range	No. in Range		% Error on Actual	Error	Actual	No. in Range		% Error on Actual	Error	No. in Range		% Error on Actual	Error
		Actual	Computed				Actual	Computed			Actual	Computed		
N_1	0-1	40	69.6	74.0	29.6	225	329.7	46.5	104.7	50	31.0	2.0	1.0	
N_2	1-2	40	36.5	8.8	3.5	129	102.5	14.6	17.5	40	39.4	1.5	0.6	
N_3	2-3	29	51.4	77.2	22.4	60	56.4	6.0	3.6	30	31.0	3.3	1.0	
N_4	3-4	27	19.8	26.7	7.2	30	36.4	21.3	6.4	25	27.0	8.0	2.0	
N_5	4-5	20	17.1	14.5	2.9	20	14.9	25.5	5.1	20	17.7	11.5	2.3	
N_6	5-6	15	20.6	37.3	5.6	15	17.8	18.7	2.8	20	19.4	3.0	0.6	
N_7	6-7	13	9.1	30.0	3.9	12	15.0	25.0	3.0	20	21.5	7.5	1.5	
N_8	7-8	10	6.4	36.0	3.6	10	9.2	8.0	0.8	15	13.4	10.7	1.6	
N_9	8-9	9	9.9	10.0	0.9	5	4.6	8.0	0.5	10	10.3	3.0	0.3	
N_{10}	9-10	8	4.3	46.2	3.7	3	3.3	10.0	0.3	5	5.1	2.0	0.1	
Total	.....	211	244.7	16.0	33.7	500	589.8	18.0	89.8	235	235.8	0.4	0.8

Table 4.—Variation of ϵ and Size Class with Drum Speed and Multivibrator Frequency

ϵ = fraction of size class

Note: See Table 3 for speed code.

Negative Magnification: 15X						
MV freq.	2500 cycles/sec.		5000 cycles/sec.		10,000 cycles/sec.	
Speed Code	ϵ	Class size	ϵ	Class size	ϵ	Class size
I	0.049725	99.9192	0.099450	49.9596	0.19890	24.9798
IIA	0.024658	139.950	0.049316	69.9751	0.098632	34.9876
IIB	0.050541	139.950	0.101081	69.9751	0.202163	34.9876
Negative Magnification: 25X						
I	0.049725	59.9515	0.099450	29.9758	0.19890	14.988
IIA	0.024658	83.9702	0.049316	41.9851	0.098632	20.9926
IIB	0.050541	83.9702	0.101081	41.9851	0.202163	20.9926
Negative Magnification: 35X						
I	0.049725	42.8224	0.099450	21.4112	0.19890	10.7056
IIA	0.024658	59.9788	0.049316	29.9894	0.098632	14.9947
IIB	0.050541	59.9788	0.101081	29.9894	0.202163	14.9947
Negative Magnification: 50X						
I	0.049725	29.9758	0.099450	14.988	0.19890	7.494
IIA	0.024658	41.9851	0.049316	20.9926	0.098632	10.4963
IIB	0.050541	41.9851	0.101081	20.9926	0.202163	10.4963

Figures 11 to 14 present additional results for actual spray droplets, and afford further confirmation of the validity of the foregoing theory and the reliability of the mechanical and electronic elements of the counter.

Data for Figures 10 through 14 are tabulated in Tables 6 through 9.

Comment

Results of performance tests on the counter to date indicate that it should be a useful and reliable tool for accelerating the process of counting and classifying drop images on photographic negatives. Data in Figures 10-14 show reasonable agreement with manual counts. As the study of this device proceeded, it appeared, in many instances, that the counter was more reliable than manual counting. This was discovered when serious discrepancies occurred between the counter and manual results. In most cases, a check of the two methods showed that the counter gave the more correct result, and that human errors had occurred in the manual count.

Successful operation of the counter depends greatly on the preparation of satisfactory negatives. Suitable negatives should be free of background imperfections or blemishes; the drops should be sharply in focus, and the black portion of the negative should be opaque enough to prevent the transmission of any light that might cause a signal. Figure 2 shows a typical negative used on the counter. It was found, however, that pinpoint imperfections in the nega-

Table 5.—Speed Code for Scanning Drum

(Refer to gear arrangement shown in Figure 9)

DRUM ROTATIONAL SPEED		GEAR DESIGNATION	
Drum Rotation Rate I:	234.783 rev./min.	a: 46T;	b: 48T
Drum Rotation Rate II:	328.046 rev./min.	a: 52T;	b: 76T
A and B			
DRUM AXIAL SPEED			
Drum Axial Rate for I:	74.5275 μ /rev.	c: 71T;	d: 78T
Drum Axial Rate for IIA:	51.7637 μ /rev.	c: 33T;	d: 50T
Drum Axial Rate for IIB:	106.098 μ /rev.	c: 42T;	d: 66T

Table 6.—Actual Spray

(Data for Figures 10 and 11)

Size Class Range Microns	Size Class No.	N ₁ Counter	N ₁ Manual	f Counter %	f Manual %	ΣN_1 Counter	ΣN_1 Manual	Register Readings, ΣC_1	Chord freq., C ₁
0-30	1	27	17	7.9	5.0	27	17	29,359	1186
30-60	2	29	33	8.5	9.7	56	50	28,173	2861
60-90	3	34	34	9.9	10.0	90	84	25,312	4231
90-120	4	39	42	11.4	12.4	129	126	21,081	5673
120-150	5	96	82	28.	24.1	225	208	15,408	6689
150-180	6	69	77	20.2	22.7	294	285	8,719	4143
180-210	7	14	24	4.1	7.0	308	309	4,576	1719
210-240	8	20	16	5.8	4.7	328	325	2,857	1413
240-270	9	5	7	1.5	2.0	333	332	1,444	527
300-330	10	4	3	1.2	0.9	337	335	917	377
330-360	11	2	2	0.6	0.6	339	337	540	222
360-390	12	2	2	0.6	0.6	341	339	318	165
390-420	13	0	0	0	0	341	339	153	36
420-450	14	0	0	0	0	341	339	117	60
450-480	15	1	1	0.3	0.3	342	340	57	57
		342	340	100.0	100.0				

tives were not sufficiently large to produce an electrical pulse. In general, a negative magnification of either 35X or 50X was used, while the projection system introduced another magnification factor of about 20X. Thus, the total magnification of the original drops ranged from 700X to 1000X.

The effect of the size of the aperture in the metal foil was briefly investigated, and it was found that a 100 μ was preferable to a 50 μ aperture. The larger aperture gave pulses of higher amplitude, and usually gave a greater total chord count. This is due to the fact that, when the larger opening was used, any fuzziness occurring around the borders of the drop had less effect on the pulse amplitude than when the smaller aperture was used.

In addition to using the chord count to obtain drop-size distribution, it is also possible to use it to calculate the average drop diameter corresponding to the average projected area. Thus, the total scanned transparent area A is given by

$$A = \sum_{i=1}^n \epsilon' C_i (a_{i-1} + a_i) / 2 \quad (25)$$

where ϵ' is the distance between scanning paths, a_{i-1} and a_i are the chord lengths corresponding to the boundaries of the i -th class, and C_i are the total number of chords in the i -th size class. The number of chord size classes varies from 1 to n . The average drop area is A/N , where N is the total number of drops. Thus, the diameter corresponding to the average projected area is given by

$$D_A = 2 \sqrt{\frac{A}{N\pi}} \quad (26)$$

The procedure for establishing areas, as indicated above, leads to the interesting possibilities of using this device for integration processes, and eventually for counting and classifying irregularly shaped particles. However, these possible applications require further investigation.

Since the preparation of this paper the counter just described has been modified in certain details and used to count several million drop images. Special studies have confirmed the above preliminary findings that it is more reliable than "human counting" and that the conversion of chord distribution to drop-size distribution is relatively independent of the shape of the distribution curve.

Acknowledgments

Special credit is due to many individuals, who materially contributed to the work reported in this paper. In the early

Table 7.—Actual Spray

Size Class Microns	(Data for Figure 12)				C_i	Register Readings, ΣC_i
	N_i , Counter	N_i , Manual	ΣN_i , Counter	ΣN_i , Manual		
0-30	103	97	103	97	2949	17098
30-60	149	140	252	237	5625	14149
60-90	102	94	354	331	4389	8524
90-120	47	45	401	376	2372	3135
120-150	20	19	421	395	1149	1763
150-180	10	11	431	406	516	614
180-210	2	1	433	407	88	98
210-240	0	0	0	0	10	10
240-270	0	0	0	0	0	0
270-300	0	0	0	0	0	0
300-330	0	0	0	0	0	0
330-360	0	0	0	0	0	0
360-390	0	0	0	0	0	0

Table 8.—Data for Actual Spray

Size Class Range, Microns	(Figure 13)		Register Readings, ΣC_i	C_i
	N_i , Manual	N_i , Counter		
0-30	15	54	14,968	1241
30-60	33	27	13,727	2270
60-90	48	53	11,457	3146
90-120	32	36	8,311	2670
120-150	27	26	5,641	2218
150-180	25	25	3,423	1782
180-210	10	12	1,641	995
210-240	10	10	646	539
240-270	3	0	107	42
270-300	1	1	65	65

Table 9.—Data for Actual Spray

Size Class Range, μ	(Figure 14)		Register Readings, ΣC_i	C_i
	N_i , Manual	N_i , Counter		
0-30	44	41	28,387	1171
30-60	19	22	27,216	2421
60-90	34	36	24,795	3582
90-120	27	27	21,213	4281
120-150	47	53	16,932	5318
150-180	56	60	11,614	4864
180-210	31	45	6,750	3199
210-240	24	18	3,551	1445
240-270	5	7	2,106	707
270-300	5	4	1,399	508
300-330	4	5	891	385
330-360	0	0	506	81
360-390	0	0	425	82
390-420	0	0	343	122
420-450	3	3	221	221

stages of development W. E. Ranz, L. E. Stout, Jr., R. W. Tate, and R. H. Wetzel contributed valuable ideas and experimental assistance. W. M. Herring, Jr., assisted in the operation of the counter in obtaining performance data. Recognition is given the University of Wis-

consin Numerical Analysis Laboratory for computation of numerical coefficients and for the calculation of results on IBM punched-card machines. The Engineering Experiment Station and the Wisconsin Alumni Research Foundation provided financial support for the study.

Notation

- A = total transparent area scanned
 a_{ij} = coefficients defined by Equations (13), (14) and (15)
 b_{ik} = coefficients for converting chord distribution to drop-size distribution, Equation (22)
 C_i = total number of chords in the i -th size class
 $C(i,j)$ = expected number of chords in the j -th size class contributed by circles in the i -th class
 D = diameter of circle
 D_A = diameter based on average projected area
 d_{ik} = coefficients for calculating standard deviation
 f = number frequency of drops in size class
 N_i = number of drops in the i -th size class
 N = total number of drops in n size classes
 N_e = experimental value of N_i
 $W(D)$ = width of band lying between chords of length α and β

Greek Letters

- α = length of chord furthest from center of circle and bounding a band of width $W(D)$
 α' = distance of α from center of circle
 β = length of chord nearest center of circle and bounding a band of width $W(D)$
 β' = distance of β from center of circle
 Δ = period of multivibrator
 ϵ' = distance between scanning paths
 ϵ = distance between scanning paths expressed as a fraction of the size class
 μ = designation for micron
 σ = standard deviation
 Bars in Fig. 1 are equivalent to primes.

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Fig. 10.

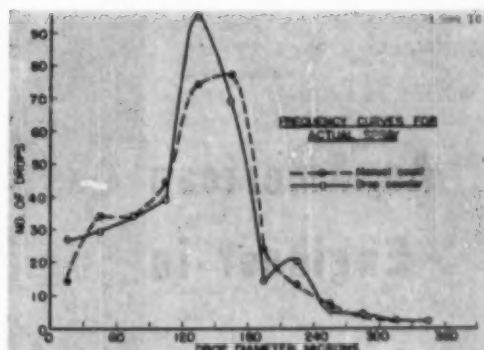


Fig. 11.

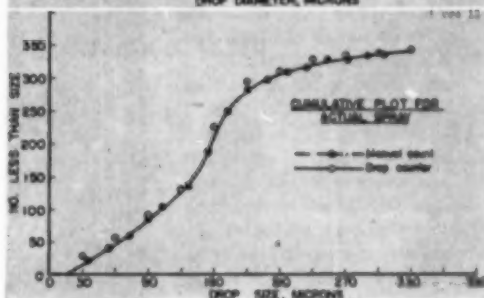


Fig. 12.

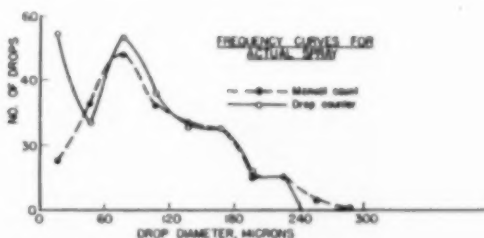


Fig. 13.

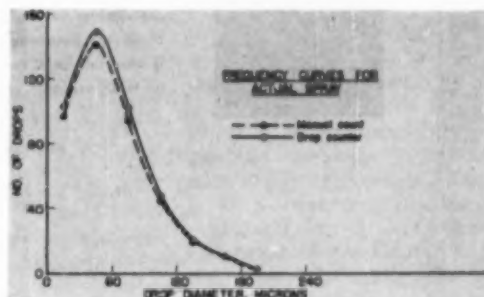
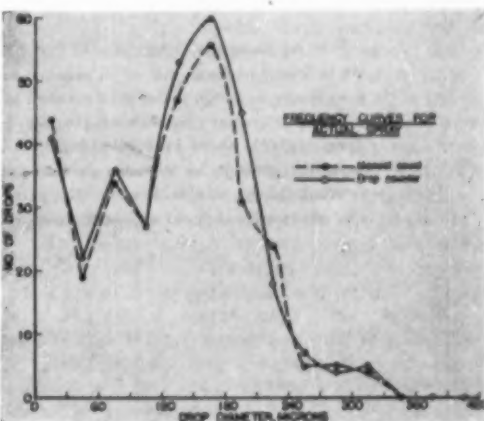


Fig. 14.



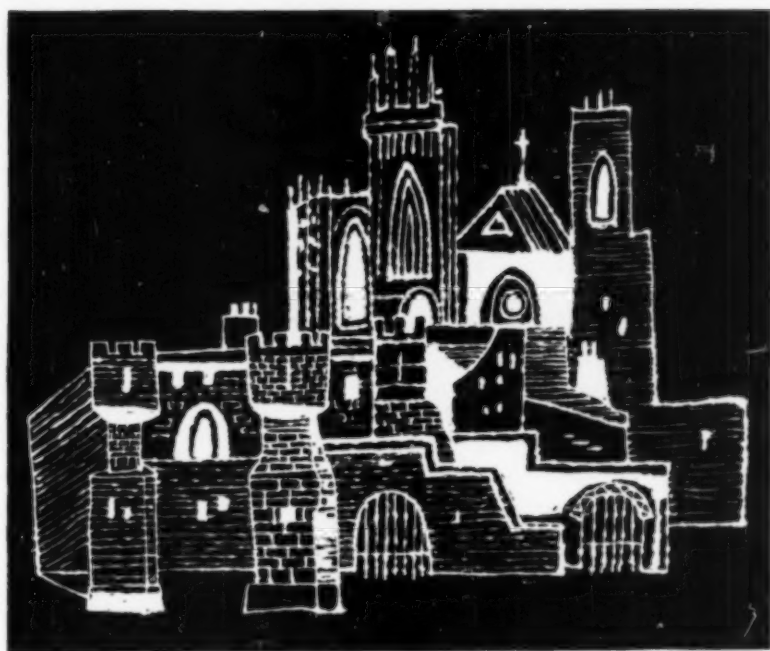
An American Chemical Engineer in England

SHELBY A. MILLER



For the past seven and one-half years Shelby A. Miller has been on the staff of Kansas University, first as associate professor and subsequently as professor of chemical engineering. He has been a participant in Monsanto's "faculty-in-industry" program. Born in Louisville, he took his B.S. in chemical engineering from the University of Louisville. Subsequently he moved to Minnesota for his Ph.D. studies, during the course of which he held an appointment as teaching assistant in chemical engineering and divided his summers between Corhart Refractories Co. and Minnesota's Northwest Research Institute. He spent six and one-half years with Du Pont as a member of what is now the Engineering Research Laboratory under T. H. Chilton, whom Miller considers a maker of teachers.

In the November, 1953, issue of CEP Edward Cullen, an English student who spent a year at the University of Texas, told of his reactions to life at an American university. In this issue we hear from Shelby A. Miller, professor of chemical engineering at the University of Kansas, Lawrence, Kan., who returned recently from a sabbatical year at Durham University's King's College, Newcastle-Upon-Tyne, England, where he held a Fulbright lectureship in chemical engineering. Professor Miller says that, although he has been concerned over a period of years with many chemical products, from refractories to nitrocotton to chlorine to laxative salts, he likes best the process material he now works with—chemical engineering students.



The excursionist who sallies through capital and countryside of a foreign nation, shooting kodachrome from the hip, and returns to his native land running over with profound observations and "expert" opinions on the geography, sociology, politics, economics, art, and industry he has encountered is no uncommon creature. His thoughtful listener or reader may be entertained or may be bored, depending on the voyager's wit, but he is certain to be indignant over assertions clothed with pseudo authority and shallowness strutting as mock depth. The difficulty, of course, derives from the erroneous belief that to travel is to sense and comprehend every influence and climate to which one is subjected. Nothing, in fact, could be farther from the truth.

It was my privilege to receive a Fulbright lectureship to an English university for the year 1952-53. This was too short a time to become an expert witness, but long enough to realize that such was the case, and for me to have many extraordinary experiences. Any observations that my family and I made outside the areas of knowledge in which we were already trained were frankly amateur and our impressions were simply those of an average university family who were a bit wide-eyed over

their first opportunity for foreign travel. With this apologia, I shall attempt to discuss the origin and probable destiny of chemical engineering in England, and then to set forth some personal reflections upon life in Great Britain.

Chemical Engineering in Britain

The term chemical engineering probably was first used in England some two or three years before its introduction in the U.S.A. It is surprising, therefore, that today the field is considerably less developed in Britain than it is here. The underdevelopment is apparent in both academic and industrial spheres.

Only eight universities offer degrees in chemical engineering and only four of these have independent departments—in the other four, chemical engineering is a division of a department of applied chemistry, fuel technology, or mechanical engineering. The largest department produces about forty B.Sc. graduates a year. Students working for the postgraduate research degree in chemical engineering (M.Sc. or Ph.D.) number about 200. The diploma-type course, in which the holder of a B.Sc. in chemistry or mechanical engineer-

ing spends an additional year or two studying chemical engineering, is still quite popular.

That chemical engineering is not more extensive in the universities of the country that developed the modern heavy chemical industry and produced one of the three largest chemical companies of the world is the direct result of the industry's own past unawareness of the value of the chemical engineer who has been trained specifically as such. That unawareness probably has reflected a lack of understanding on the part of mechanical engineers and chemists in the universities as well as in industry that chemical engineering exists and has a clear *raison d'être* as a distinct discipline; and that those qualified in this discipline fill a place in industry as process engineers that cannot be filled competently by either chemists or mechanical engineers without extensive specialized experience or additional training. Several influential voices, the loudest and clearest belonging to Sir Harold Hartley, now are evangelizing Britain, calling for proper recognition of the chemical engineer and his employment by the chemical and related industries. I believe that a day of grand expansion for British chemical engineering in both industry and university lies immediately ahead.

Research being carried on in the chemical engineering laboratories of the universities is in the areas of unit operations, thermodynamics, and kinetics and process studies. By and large it is of sound, fundamental character and is being carefully and in some instances brilliantly done. In quality it quite resembles that of U. S. universities. Chemical engineering undergraduate curricula differ somewhat from those of America in that there is often an unfortunate emphasis on mechanical design with concomitant underemphasis on chemical engineering thermodynamics, applied kinetics, and process design. As in American curricula, there is serious difficulty in fitting the bare minimum of instruction within the confines of the equivalent of our four-year course. Once the chemical engineering student has earned his B.Sc. with honors, he may pursue a Ph.D. directly with no further course work; satisfactory completion of a thesis is all that is required for a degree. The absence of red-tape and obstacle-requirements in graduate study is most refreshing; furthermore, the British undergraduate student in science or engineering is undeniably better grounded in mathematics, basic science, and language than is his American counterpart, and presumably is better equipped to continue his private un-

regimented study while he is engaged in his M.Sc. or Ph.D. research. I believe, however, that the Ph.D. graduate in England would be better qualified if he were guided through at least part of the formal instruction that is customary in American universities at the graduate level.

Life in Great Britain

If I were to offer the simplest and most concise abstract of my impressions of Britain and the British, it would consist of three words: tradition, stability, and friendliness. These three top facets of British character impacted us immediately upon our arrival in Southampton and London and remained apparent in every aspect of life as we lived it in the northern communities of Newcastle and Gateshead.

BRITISH TRADITION

Tradition and stability are physically symbolized by the incredible age of actively used structures and continuously functioning communities and institutions. A striking typical example is provided by the Durham Colleges, which occupy a centuries-old castle overlooked by the simple grandeur of a Norman cathedral (it was our favorite among the several cathedrals that we visited in England and France) dating to the eleventh century. The "new castle" for which our host city is named was erected in 1172 on the site of a more ancient structure and restored in 1808. My son attended a grammar school that had been founded in 1543, and there has been a community in the Tyne valley, where we lived, since Hadrian built his wall—still much in evidence—in 120 A.D. So ad infinitum, but never to the saturation of our American wonder and interest.

But tradition is also an active if not a totally conscious force in the daily behavior of the people. It is reflected in the ornamental regalia of the lord mayor of a city and the vice-chancellor of a university, in the wigs of barristers and judges, in the relatively formal dress of school boys and university scholars. It is reflected in the delightful custom of English dinners with their toasts and responses—and in the beautiful courtesy of no one's smoking during a formal dinner or, indeed, afterward until the Queen's health has first been toasted. It is reflected, less favorably in the American view, in the reluctance to change existing things, in the resistance to innovation, and in the residual belief in an ancestral aristocracy.

I think it is fair to say that in this respect the difference between our so-

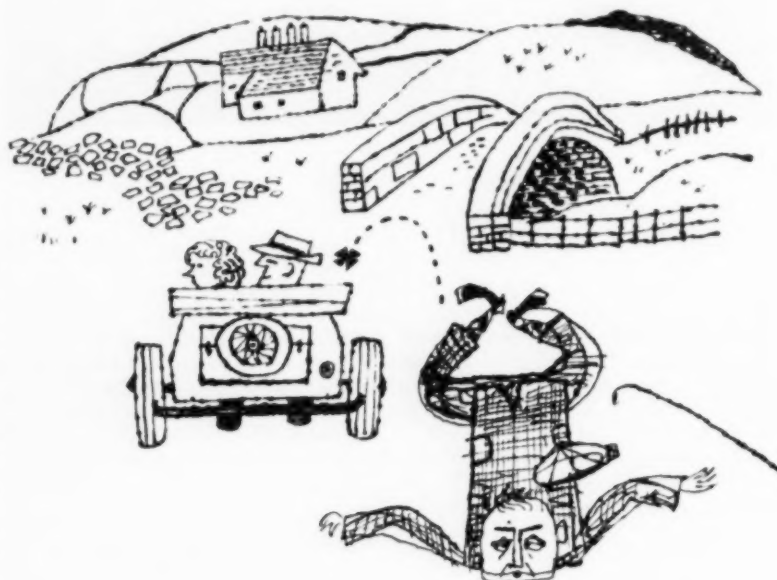
ciety and Britain's is largely one of degree—although the degree is great—and to point out that in certain matters of political and social action the English have been less tradition-bound than we.

STABILITY

The stability of the English character is difficult to describe but as unmistakable as the warmth of the sun. Without attempting to trace its historical roots, I should say it is founded on the individual traits of honesty, respect for self and fellowmen, personal responsibility, and a sharp intuition for changeless principle as distinct from shifting modes. These characteristics help ex-

illustrated by our being the houseguests of our professor and his wife for the first four weeks and of the senior lecturer and his wife for the last two weeks of our stay. It had a sort of acid test when, at the close of my second day of driving an English car, I walked into a police station to report that I had bowled over a pedestrian (fortunately he was not much injured). It explained the lumps in our throats as the Tees-Tyne Pullman carried us southward out of the Newcastle station for the last time.

Space forbids my writing of the new and old sectors of the British process industry; of English university life—an accurate contrast with American



plain the existence of an extremely orderly society with the minimum of coercion, the phenomenon of an unarmed policeman, the fact of a *Loyal Opposition* that is none the less identified with a true two-party political system.

A FRIENDLY PEOPLE

I say simply that British friendliness and kindness we found to be equal to any we have experienced at home. It began with dock hands and hotel clerks, taxi-drivers and trainmen while we were en route to our college. But it found its climax in the unfailing generosity and hospitality of our hosts in the Newcastle area. It is accurately

university life was given by Cullen (1); of the strong interest among our British friends in international and particularly American affairs; of the successful nationalization program; of the delightful English pub; of the many other things that made my year a thoroughly fine one. Suffice it to say that Britain, our nearest kin in the European community, is a friend worth having, and to know more of her and her ways and her people should be a valuable and pleasant experience for every American.

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Pipe-Line Design for Non-Newtonian Fluids

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A new and general method is presented for predicting the pipe-line pressure-drop requirements for the laminar flow of non-Newtonian fluids. This method may be used for predicting from laboratory data alone the effect of changes in operating variables such as flow rate, temperature, and solids content of the fluid and diameter of the pipe line. When no data are available, the method may be used as a basis for the design of a model on which a single determination will provide the desired information about the full-scale prototype.

The method is shown to be applicable to all fluids except those whose rheological characteristics change with time (thixotropic or rheopectic) and dilatant slurries, on which no data were available. For Newtonian fluids the method reduces to the usual Poiseuille equation. The generality and utility of this method are shown by correlation of data on five plastic and pseudoplastic fluids in pipes ranging in diameter from 1/2 to 3 in.; average linear velocities of the fluids studied varied from 0.27 to 7.0 ft./sec. and apparent Reynolds numbers varied from 0.43 to 1910. The fluid properties were determined with three different viscometers.

Satisfactory design methods for prediction of the pressure drops required for flow of non-Newtonian fluids in pipe lines have not kept pace with the rapidly increasing importance of this problem in industry. This is especially true of the highly non-Newtonian slurries of high-solids content which are frequently encountered in the petroleum and detergents industries. The purpose of the present paper is to provide an accurate semitheoretical means of readily correlating and predicting the behavior of such fluids in pipe lines.

Figure 1 is a diagram of the isothermal shear-rate-shear-stress relationships of a Newtonian fluid and of plastic, pseudoplastic, and dilatant non-Newtonian fluids. Table 1 gives examples of fluids exhibiting each of the three types of non-Newtonian properties and indicates that most of the industrially important fluids exhibit either plastic or pseudoplastic behavior.

Thixotropic and rheopectic fluids with rheological properties dependent on time of shear as well as on rate of shear are not dealt with in the present paper. It may be noted, however, that many of the reported variations in rheological properties with time of shear are not due to inherent thixotropic or rheopectic properties of fluid but are due only to changes in temperature of the fluid being sheared. Thus the industrial occurrence of fluids which are truly thixotropic or rheopectic is much more infrequent than is often assumed.

Table 1.—Examples of Non-Newtonian Fluids

Type of fluid	Industrial examples
Plastic	Drilling muds (5), sewage sludge (4), cement rock slurries (10), grain suspensions (2), chalk suspensions (3)
Pseudoplastic	Napalm (1), cellulose acetate in acetone (1), paper-pulp suspensions (8), mayonnaise (8), some paints and lacquers (8), detergent slurries
Dilatant	Starch suspensions (8), quicksand (8)

Further discussions of the occurrence and peculiarities of non-Newtonian fluids are found in recent reviews of this subject (1, 6, 8).

Calculation of Pressure Drop in Pipe Lines

For Newtonian fluids the standard Fanning method (8, 9), involving the use of friction factors, is entirely satisfactory. For plastic or Bingham plastic

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non-Newtonians, Govier and Winning (5) and Hedström (7) have modified the Fanning method, the result of their work being the establishment for the first time of a completely rigorous yet simple method for calculating pipe-line pressure drop for this class of non-Newtonians. Thus the major practical need for further work falls into two categories:

a. development of design methods generally applicable to all pseudoplastic and dilatant fluids

b. development of a general method applicable to all four types of industrially important fluids, i.e., Newtonians, Bingham plastics, pseudoplastics, and dilatant fluids. This need is a result of the difficulty of definitely classifying a new fluid as being of one type or another and of the tendency of a fluid or slurry to change from one type to another with small changes in temperature or composition. Only one such general method for predicting pipe-line pressure drops has been published to date. This prior-art method (1) represents an excellent theoretical approach to the problem, but the data presented indicate that the accuracy is sometimes rather limited when the method is applied to the design of pipe lines of practical diameters. Since the calculations required are rather tedious and are not applicable to the various viscometers having a complicated and nonideal spindle geometry, it was felt that a new, more empirical approach to supplement the prior art was justified.

Development of Correlation

With the extremely viscous slurries of high solids content of major interest in this paper, prohibitively high pressure gradients are usually encountered if flow rates are increased into the turbulent region. As a result, laminar flow is of primary interest and for the present this development accordingly restricts itself to the laminar-flow region.

For the laminar flow of a Newtonian fluid, Poiseuille's law (9) is applicable:

$$\Delta P = \frac{32\mu VL}{g_c D^2} \quad (1)$$

This equation can also be made applicable for laminar flow of a non-Newtonian fluid by substitution of a judiciously chosen apparent viscosity, μ_a , for the true viscosity μ of a Newtonian fluid.

Reference to Figure 1 shows that the apparent viscosity of a non-Newtonian fluid ($\mu_a = \tau g_c / n$, i.e., the tangent of the angle AOC for pseudoplastic fluids) varies with the rate of shear of the fluid. Observation of the fluid behavior in a viscometer, especially in a rotational unit (Fig. 2), indicates that the bulk of the fluid is being sheared at only a very low rate. In other viscometers, although the rate of shear may be higher, it will still not be identical with the shear rate at the wall of a pipe except in rare, for-

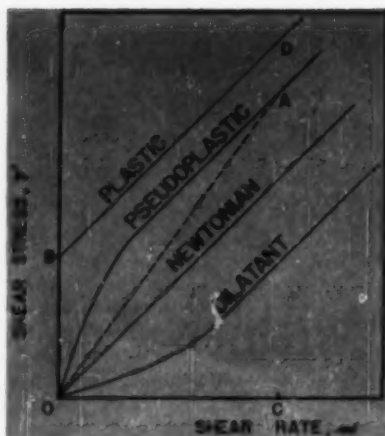


Fig. 1. Shear diagram for common fluids.

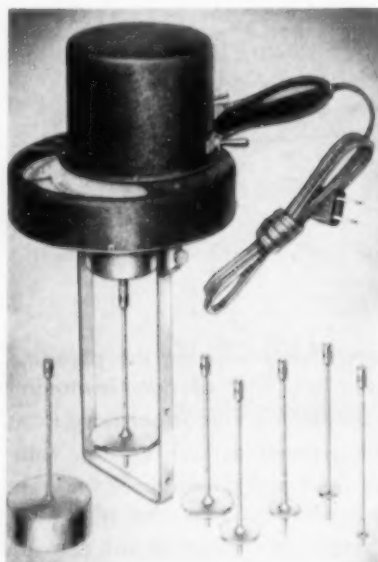


Fig. 2. Brookfield viscometer.

truitous circumstances. In either case, therefore, the apparent viscosity determined in the laboratory is not directly applicable to the practical problem of flow in a conduit.

The basic assumptions of the present development are as follows:

1. The shear rate in a pipe was assumed to be a unique function of the ratio V/D . This may be shown to be rigorously true for the fluids under discussion.
2. The shear rate in a rotational viscometer was assumed to be a unique function of n , the rotational speed. This is also a rather obvious assumption.
3. The third and major assumption was that the functional forms of both the relationships stated above are identical. If this is the case then the ratio of the shear rate in a pipe to

that in a viscometer is a unique function of the dimensionless ratio V/nD .

The validity of this third assumption may be readily established for Newtonian fluids if the viscometer consists of an ideal system of two large concentric cylinders of nearly equal radii. It must be emphasized that for non-Newtonian systems, where the viscometer used does not have such an ideal geometry, this relationship has not been theoretically justified. However it will be proved experimentally for the systems and ranges of variables used in the present study.

Conversion of the viscosity obtained on a laboratory rotational viscometer, μ_L , to an apparent viscosity μ_a , which is correct for the particular pipe-line design and flow rate in question, by means of the shear rate ratio V/nD will permit the calculation of the actual pressure drop in the pipe line. Alternately, the laboratory viscosity may be used directly in Poiseuille's law to obtain a calculated pressure drop:

$$\Delta P_{calc.} = \frac{32\mu_L VL}{g_c D^2} \quad (1a)$$

This calculated pressure drop can then be converted to the actual pressure drop in the pipe line (ΔP_{actual}) by means of the ratio of the shear rate in the pipe to that in the viscometer as expressed by the ratio V/nD .

In practice the second alternative is more direct. The functional relationship between the two dimensionless ratios $\Delta P_{calc.}/\Delta P_{actual}$ and V/nD is most conveniently determined graphically. Although the derivation is restricted to viscometers with only one combination of bob and cup, the results are applicable within limits to other combinations, as will be shown by data later.

Experimental Proof of Correlation

Figure 3 shows the unique relationship between these two dimensionless groups, for data obtained on a detergent slurry in $\frac{1}{2}$ -, 2-, and 3-in. pipes. Table 2 gives the conditions used in each set of runs. ΔP_{actual} is the actual measured pressure drop in the pipe line at flow rate V . The laboratory apparent viscosity μ_D , determined at the same fluid temperature with a Brookfield viscometer, was used with Poiseuille's law to obtain $\Delta P_{calc.}$ The following significant conclusions may be drawn:

1. The diameter of the pipe line had no measurable effect on the correlation, even though the largest pipe had $4.9 \times$ I.D. of the smallest.
2. The laboratory viscosity data may be determined at any convenient viscometer shear rate; all four Brookfield speeds correlate equally well.

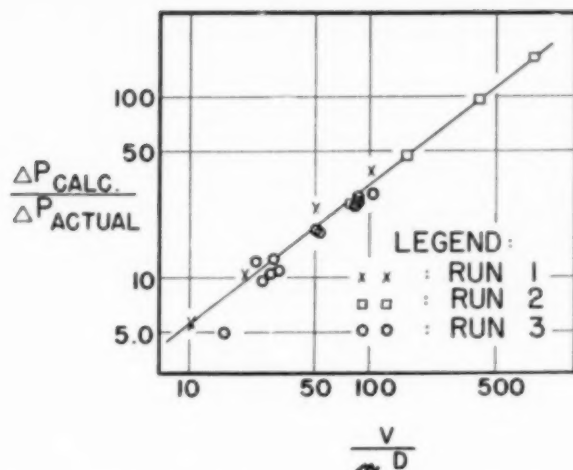


Fig. 3. Calculation of pressure drop in pipe lines: detergent slurry type A.

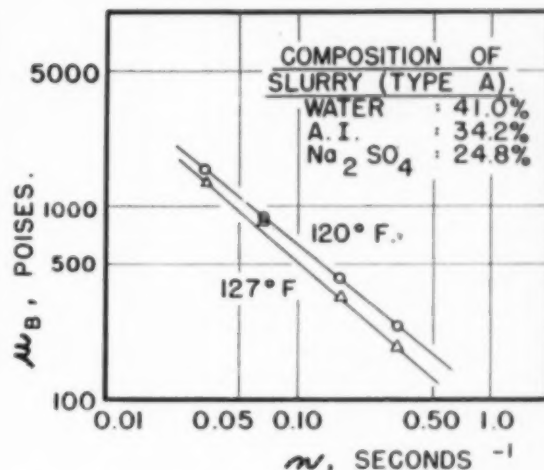


Fig. 3A. Apparent viscosities of type A detergent slurry.

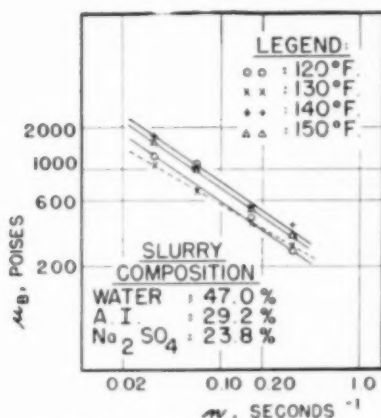


Fig. 3B. Apparent viscosities of type A detergent slurry.

Table 2.—Auxiliary Data for Figure 3

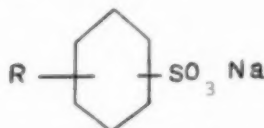
Run number	1	2	3
Temperature, °F.	127	120	119-132
Velocity, V, ft./sec.	0.865	4.35	0.27-1.80
Pipe, I.D., in.	3.068	1.939	0.622
Brookfield viscometer spindle number	5	6	6
Shear rate n , sec. ⁻¹	0.33-0.033	0.33-0.033	0.33
Slurry composition:			
Water, %	41.0	41.0	47.0
A.I., %	34.2	34.2	29.2
Na ₂ SO ₄ , %	24.8	24.8	23.8

Viscometer Spindle Dimensions:

Spindle number	Shaft dimensions, in.		Disc dimensions, in.	
	Diam.	Immersed length	Diam.	Thickness
5	0.125	1.87	0.84	0.065
6	0.125	1.87	0.58	0.065

3. There was no effect of temperature over the 33° range used. The apparent viscosity (at $n = 0.166$ sec.⁻¹) ranged from 410 to 580 poises over this temperature range.

Additional plots for two other detergent slurries of different compositions are given in Figures 4 and 5. In all instances the term A.I. refers to the active ingredient or organic sulfonate salt of the detergent composition. The A.I. of the detergent slurries used herein has the approximate formula



where R is predominantly the tetramer of propylene.

Type A and Type C slurries are distinctly different in their ratio of A.I./Na₂SO₄. Type B is essentially a Type A slurry with silicate added.

Although the intercept of the various curves on the ordinate $V/nD = 10$ was changed by these changes in composition, the slope of the correlating lines is identical for all these synthetic detergent slurries. The mean deviation of these data from the correlating lines is only 15%, excellent for engineering correlations of this type.

Figures 3A, 3B, 4A, and 5A give apparent viscosities of these detergent slurries as a function of viscometer speed or shear rate. It is evident that the slopes of these figures are identical numerically to those for the corresponding slurry in Figures 3 to 5. This means that the laboratory viscosity can be determined at any convenient shear rate, and when combined with the appropriate plot of $\Delta P_{\text{calc}}/\Delta P_{\text{actual}}$ vs. V/nD , will always give the same value of ΔP_{actual} for a given problem. This is due to the fact that this method of pressure-drop prediction consists essentially of extrapolation of the laboratory viscosity to

the proper shear rate for the pipe-line problem in question. When the slopes of both the $\Delta P_{\text{calc}}/\Delta P_{\text{actual}}$ vs. V/nD and the μ_L (or μ_B) vs. n plots are numerically identical, the extrapolation may be carried out on either one.

Literature data on other non-Newtonian systems were correlated in the same manner. Figure 6 shows a correlation for the cement-rock slurries of Wilhelm, Wroughton, and Loeffel (10); Figure 7 was drawn up from the data on Illinois-yellow-clay suspensions reported by Caldwell and Babbitt (4).

The detergent slurries all exhibited some form of pseudoplastic behavior; both the cement-rock slurries and the clay suspensions are stated (10, 4) to be plastics as defined by Figure 1. These data therefore show that the correlating technique presented is of general applicability for both types of fluids. No literature data were found on the flow of dilatant slurries; these are encountered much less frequently in industrial prac-

tice than are plastic or pseudoplastic fluids, however, and therefore their absence does not greatly limit the utility of these correlations.

Figures 6A and 7A show the apparent viscosities of cement-rock suspensions and Illinois-yellow-clay slurries as a function of shear rate or viscometer speed. These apparent viscosities were calculated from data given in the respective papers. In the case of the cement-rock suspensions the viscosities were obtained on a laboratory instrument similar to the Interchemical Rotational viscometer; the properties of the yellow-clay slurry were deduced from measurements in a pipe line.

It is evident that although the slopes of the curves of Figures 3A, 3B, 4A, and 5A are numerically identical to the slopes of the pressure-drop curve for the corresponding slurry in Figures 3, 4 and 5, the slopes of Figures 6A and 7A are not numerically identical to those of Figures 6 and 7 respectively. As a result, for these plastic non-Newtonian fluids the correlation must be based on any one arbitrary viscometer shear rate since the necessary shear rate extrapolation can be made only on the $\Delta P_{calc.}/\Delta P_{actual}$ vs. V/nD plots. The viscometer speed chosen for Figure 6 was 150 r.p.m. ($n = 2.50 \text{ sec.}^{-1}$); Figure 7 is based on a shear rate of $n = 100 \text{ sec.}^{-1}$.

The mean deviation of all the data from the pressure-drop correlating lines is only 11%.

Use of This Correlating Technique as a Design Procedure

In essence this technique is one of utilizing limited data obtained on a model of convenient size to predict the pressure drop of the same or of a rheologically similar fluid under new conditions—frequently conditions under which a measurement of the pressure drop is not possible or economic.

The following steps are taken:

1. Laboratory viscosity data and pressure measurements at various velocities (all in laminar flow) are taken with the fluid in question in a pipe line of convenient size. If, as in the case of detergent slurries, temperature has an important effect on the fluid properties, both sets of measurements must, of course, be at identical temperatures.
2. Logarithmic plots of $\Delta P_{calc.}/\Delta P_{actual}$ vs. V/nD and of apparent viscosity μ_a vs. n are drawn. If the numerical values of the slopes of both are identical, then subsequent viscosity measurements or calculations may be made at any convenient value of n ; such was the case with the pseudoplastic detergent slurries tested.

If the numerical values of the slopes of both figures are not identical, as was the case with the plastic slurries of cement rock or yellow

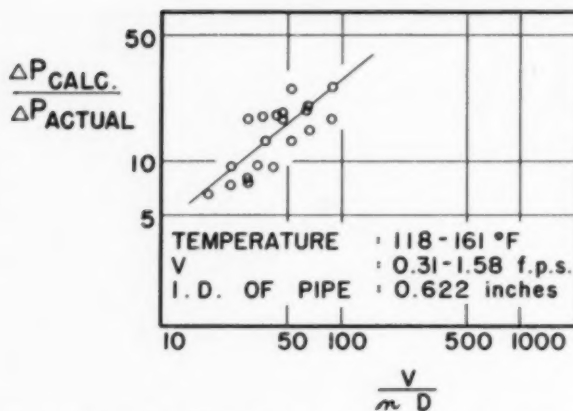


Fig. 4. Calculation of pressure drop in pipe lines: detergent slurry type B.

Slurry composition:

water	49.6%
A.I.	23.7%
Na ₂ SO ₄	19.2%
Na ₂ O · 3.25 SiO ₂	7.5%

Brookfield Spindle: #6
 n (seconds⁻¹): 0.33

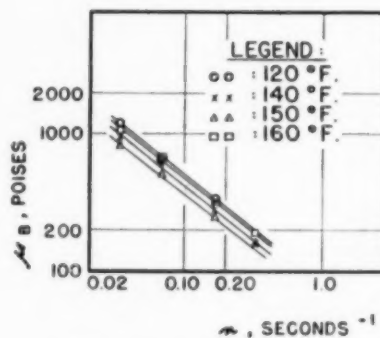


Fig. 4A. Apparent viscosities of type B detergent slurry.*

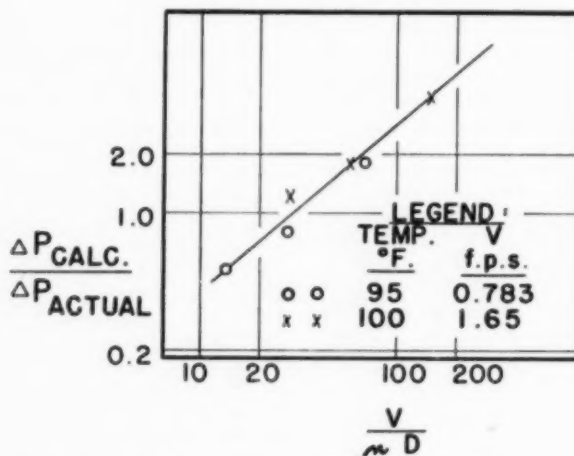


Fig. 5. Calculation of pressure drop in pipe lines: detergent slurry type C.

Slurry composition:

water	48.7%
A. I.	42.6%
Na ₂ SO ₄	8.7%

I.D. of pipe: 2.067 in.
Brookfield spindle: #5
 n (seconds⁻¹): 0.33 — 0.066

clay, the plots of $\Delta P_{\text{calc.}}/\Delta P_{\text{actual}}$ vs. V/nD must be based on any one fixed value of n which is arbitrarily chosen.

3. If the problem is to predict the pressure drop of the same fluid at the same temperature in a pipe of different diameter and/or at a flow rate different from that used in drawing up the plot, then the plot is used directly to obtain ΔP_{actual} for the new values of V/nD and $\Delta P_{\text{calc.}}$.
4. If the problem is to predict the pressure drop of this fluid at a new temperature, this can be done by measuring the fluid properties at this new temperature with the laboratory viscometer, calculating $\Delta P_{\text{calc.}}$ and then using the graph to obtain ΔP_{actual} . It has been found that good results are obtainable in

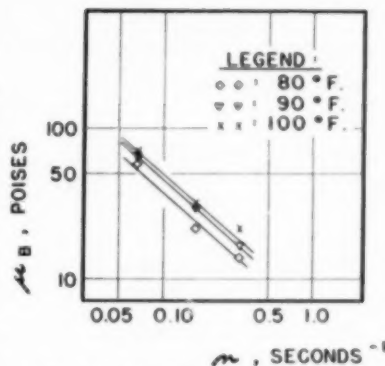


Fig. 5A. Apparent viscosities of type C detergent slurry.

PROBLEM 1. A 2-in. pipe line is to be designed to carry 40 gal./min. of an aqueous synthetic detergent slurry. No laboratory data can be obtained but a 1/2-in. pipe line is available. What is the predicted pressure drop in the 2-in. line?

SOLUTION. Since no laboratory data can be obtained, it is impossible to draw a plot of $\Delta P_{\text{calc.}}/\Delta P_{\text{actual}}$ vs. V/nD using the 1/2-in. pipe line. However the 1/2-in. line may be used as a model of the 2-in. prototype, as follows. For a given fluid and fluid temperature, there is only one value of $\Delta P_{\text{calc.}}/\Delta P_{\text{actual}}$ for a given value of V/nD . Therefore if the flow rate in one experimental run in the 1/2-in. pipe is so chosen that V/D is the same as for a flow rate of

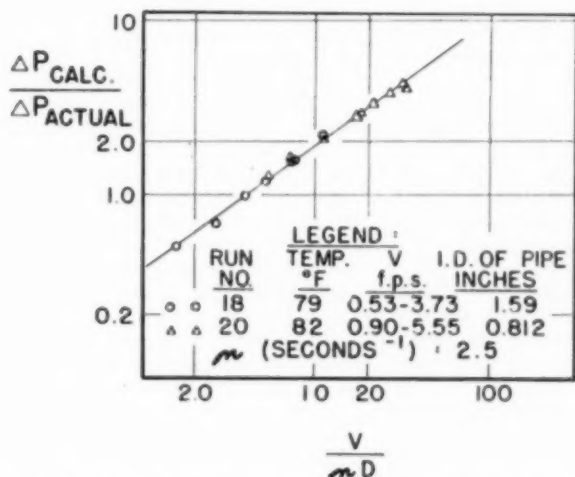


Fig. 6. Calculation of pressure drop in pipe lines for cement-rock slurries.

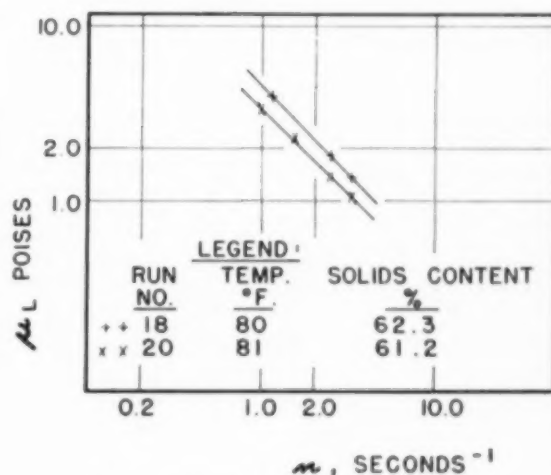


Fig. 6A. Apparent viscosities of cement-rock slurries.

this manner over wide ranges of temperature. Since this is an extrapolation, however, judgment is necessary to avoid excessive extrapolations. For example, detergent slurries gel in certain temperature regions, and data obtained in a nongelling region cannot, of course, be used to predict the pressure-drop characteristics in the gelling region.

It has been found that the logarithmic plots of μ_L vs. n afford the key with which to determine whether a given extrapolation is allowable or not: when the slope of this plot for the fluid under the new conditions is identical or nearly identical with the slope of the same plot under the conditions of the original pressure-drop data, then the extrapolation has been found to be allowable even though the magnitude of the apparent viscosity at a given shear rate has changed. When the slopes are not identical but the new data are nevertheless used as a basis for pressure-drop calculations, the percentage error in the pressure drop has been found to be of about the same magnitude as the percentage difference of the two slopes.

In all cases care must be exercised to ensure that any extrapolations do not carry the flow out of the laminar region, since these correlations have not yet been tested for turbulent-flow conditions. Probably the best test for laminar flow of a pseudoplastic fluid is that the Reynolds number, based on the actual apparent viscosity of the fluid for the flow rate and pipe size in question, is not greater than about 2100. Such an actual apparent viscosity can be calculated from the ΔP_{actual} obtained from the logarithmic plots of the two dimensionless ratios. This is believed to give a good indication of the onset of turbulence and for plastic fluids closely agrees with the true criteria of laminar flow presented elsewhere (5, 7).

5. When no data are available on a given slurry, the method may be used as a basis for the design of a model of convenient size on which data may be obtained to predict the pressure drop in a large prototype.

The following examples illustrate the use of this design procedure.

40 gal./min. in the 2-in. pipe, it follows that

$$\frac{(\Delta P_{\text{calc.}})_p}{(\Delta P_{\text{actual}})_p} = \frac{(\Delta P_{\text{calc.}})_m}{(\Delta P_{\text{actual}})_m}$$

where subscript p is used for the 2-in. prototype and m for the 1/2-in. model. If Equation (1a) is introduced,

$$\left(\frac{32\mu_L}{g \cdot D} \frac{V}{D} \right) / \Delta P_{\text{actual}} \Big|_p = \left(\frac{32\mu_L}{g \cdot D} \frac{V}{D} \right) / \Delta P_{\text{actual}} \Big|_m$$

Since for the same value of V/D the apparent viscosity is the same in both pipes, this reduces to the following:

$$\frac{(\Delta P_{\text{actual}}/L)_p}{(\Delta P_{\text{actual}}/L)_m} = \frac{D_m}{D_p}$$

Diameters of the pipe lines are as follows:

1/2-in. pipe: 0.622 in.
2-in. pipe: 2.067 in.

For the case under consideration, therefore,

$$(\Delta P_{actual}/L)_p = \frac{0.622}{2.067} (\Delta P_{actual}/L)_m$$

That is, the actual pressure drop in the 2-in. line can be calculated from a single run in the 1/2-in. pipe. The flow rate used in this run is calculated as follows:

$$(V/D)_p = 22.2 \text{ sec.}^{-1}$$

$$= (V/D)_m$$

$$V_m = 22.2 \times \frac{0.622}{12}$$

$$= 1.15 \text{ ft./sec. (1.09 gal./min.)}$$

Experimentally it was found that at this velocity the pressure drop in the 1/2-in. model was 2.46 lb./sq.in. (ft. of length). Therefore for the 2-in. line at 40 gal./min. it is predicted that

$$\Delta P_{actual}/L = \frac{0.622}{2.067} \times 2.46$$

$$= 0.74 \text{ lb./sq.in. (ft. of length)}$$

This value is within 3% of the measured pressure drop of 0.72 lb./sq.in. (ft.) in the 2-in. line at the flow rate of 40 gal./min. In passing, it may be noted that the pressure drop in the 2-in. line obviously could not have been predicted from a determination made in the 1/2-in. line at the same linear fluid velocity, a procedure not infrequently recommended in the literature.

PROBLEM 2. The pressure drop of Type C detergent slurry in a 3-in. (schedule 40) pipe 150 ft. long is to be calculated. The design flow rate is 38 gal./min., the fluid temperature 180° F., and the analysis of the slurry is as follows:

Water: 48.7%
A.I.: 42.6%
Na₂SO₄: 8.7%

SOLUTION. A plot of ΔP_{actual} vs. V/nD is already available for this slurry (Fig. 5). It was drawn from data obtained at 95°-100° F. in a 2-in. pipe.

Measurement of the apparent viscosities of this slurry at 180° F. with a laboratory Brook-field viscometer gave the following results:

μ_s poises
20 r.p.m. 6.30
10 r.p.m. 12.5
4 r.p.m. 27.0
2 r.p.m. 44.0

The slope of these data on a logarithmic plot of μ_s vs. n is -0.86 , identical to the slope of Figure 5A for slurries of this composition and numerically equal to the slope of Figure 5. This confirms the applicability of Figure 5 under these new conditions.

For the 3-in. pipe:

$$D = 0.256 \text{ ft.}$$

$$V = 1.65 \text{ ft./sec.}$$

$$n = 0.166 \text{ sec.}^{-1} \text{ (10 r.p.m. arbitrarily chosen)}$$

$$\text{Therefore } V/nD = 38.6$$

From Figure 5

$$\Delta P_{calc.}/\Delta P_{actual} = 1.25$$

$$\Delta P_{calc.} = \frac{32\mu_s LV}{g_c D^3} =$$

$$\frac{32 \times 0.000672 \times 12.50 \times 100 \times 150 \times 1.65}{32.2 \times (3.07)^3}$$

$$= 2.20 \text{ lb./sq.in.}$$

$$\Delta P_{actual} = \frac{2.20}{1.25} = 1.75 \text{ lb./sq.in.}$$

This is the actual predicted pressure drop. Since the mean deviation of the data in Figure 5 is 9%, this would be the probable accuracy of the answer. However in view of the large temperature extrapolation involved, a safety factor of about 20% is advisable.

PROBLEM 3. Calculate the pressure drop of a Type A detergent slurry in 194 ft. of 3-in. (schedule 40) pipe. The flow rate is to be 5.5 gal./min., the slurry is 62% solids, its temperature (as pumped) is 110° F., and it has a specific gravity of 1.30 at this temperature.

SOLUTION. Figure 3, the appropriate $\Delta P_{calc.}/\Delta P_{actual}$ vs. V/nD plot for similar slurries at slightly higher temperatures, will be assumed applicable to this problem. Since no viscosity data are available for the present conditions (62% solids, 110° F.), it will be further assumed that the 120° F. curve of Figure 3A (59% solids) is sufficiently close to the true viscosity curve for engineering purposes. This is justifiable in the light of the fact that these two factors (temperature, solids content) tend to cancel each other at the temperature level in question for these slurries.

Then,

$$D = 0.256 \text{ ft.}$$

$$V = 0.238 \text{ ft./sec.}$$

$$\mu_s = 430 \text{ poises when } n = 0.166$$

$$\frac{V}{nD} = 5.58$$

Therefore from Figure 3

$$\Delta P_{calc.}/\Delta P_{actual} = 3.6$$

$$\Delta P_{calc.} = \frac{32\mu_s LV}{g_c D^3} = 141 \text{ lb./sq.in.}$$

$$\Delta P_{actual} = \frac{141}{3.6} = 39 \text{ lb./sq.in.}$$

This is within 10% of the measured value of 43 lb./sq.in. in the actual 3-in. line.

Discussion and Comparison with Prior Art

In the method presented three groups of variables are significant: the dimensionless ratios $\Delta P_{calc.}/\Delta P_{actual}$ and V/nD , and the stress-strain relationships of the fluid. At the present stage of development the effect of the last group of variables is eliminated by always using the same fluid in both the laboratory and the pipe-line measurements, although not necessarily at the same temperature or solids content. Both of these factors may be varied over a considerable range; this range is limited only by the required constancy of the shape of the logarithmic plots of μ_s vs. n .

The method presented here has all the advantages associated with the Theory of Models; data taken under convenient conditions on a model of convenient dimensions may be used to predict the behavior of a large-scale prototype. In this case both the stress-strain relation-

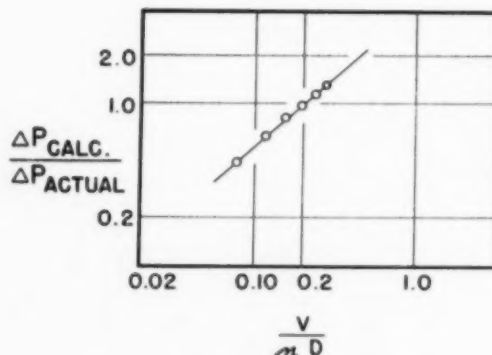


Fig. 7. Calculation of pressure drop in pipe lines for Illinois-yellow-clay slurry.

Solids content of slurry: 48%
I.D. of pipe (assumed): 3.068 in.
V: 2.0-7.0 ft./sec.
Shear rate: $n = 100 \text{ seconds}^{-1}$

ships of the fluid and the dimensionless ratio V/nD are kept constant during scale-up from model to prototype; the former by using the identical fluid under identical temperature conditions in both model and prototype, and the latter by operating the model with the same V/D as will be used in the prototype.

The illustrative model-design problem dealt with a pseudoplastic slurry; it can be shown theoretically that models used for prototype pressure-drop prediction may also be designed on the basis of constant V/D for all fluids whose properties are not time dependent, provided the flow is in the laminar region. Thus for purposes of model design for a new fluid with properties not known in detail it is not necessary to determine into which of these classes the new fluid falls; it is only necessary to shear the fluid for a sufficient period of time to note the absence of time-dependent properties such as thixotropy and rheopexy and to scale-up at constant V/D . To the author's knowledge these criteria for proper model design have not been pointed out before and from a practical viewpoint may possibly constitute the most important contribution of this paper.

The method is general and is easy to use. The only other method of general applicability to both plastic and pseudoplastic fluids (1) involves more tedious calculations, and if it is judged from the single plot presented for comparing laboratory measurements with laminar-flow data obtained in pipe lines of commercial diameter, the results obtained in a pipe line of small diameter or with a laboratory viscometer do not appear to predict as accurately the pressure drop in a larger pipe line. Therefore the method presented in this paper is believed to be of greater utility in the laminar-flow region, particularly when substantial extrapolations of the shear rates are involved. It should be pointed out, however, that in those instances where neither a general method nor one applicable to pseudoplastic fluids is desired, the excellent procedures developed for and restricted to plastic fluids (5,7) are entirely satisfactory and superior to these general methods.

The present method is believed to be the only one general for non-Newtonian fluids in which laboratory measurements are combined with data obtained on a model or prototype to give a unique correlation. This correlation can then be used to predict from laboratory data alone the behavior of a similar fluid but under new conditions of temperature, solids content, flow rate, and pipe-line diameter. The alternate prior-art method (1) is used to predict the pressure drop in a pipe line from laboratory data di-

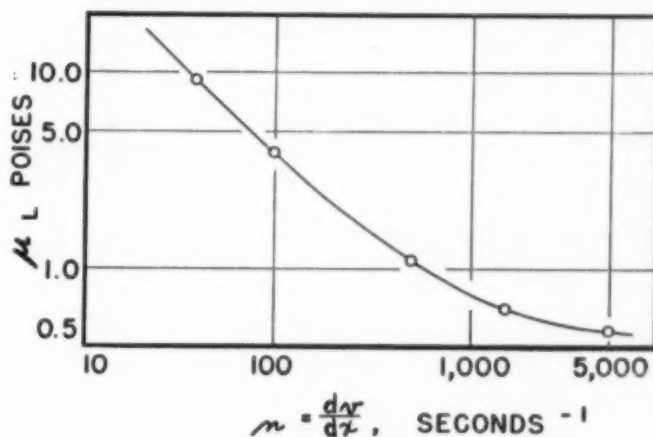


Fig. 7A. Apparent viscosities of Illinois-yellow-clay slurry.

rectly. It is to be expected that the present method (i.e., the one in which laboratory data are combined with pipe-line measurements) would give higher accuracy, and the results presented in both papers bear this out.

The present method has a distinct advantage over others in that the laboratory data can be taken with viscometers having measuring elements of complicated geometry. Since such viscometers are at present the most widely used by far, this technique enables the interpretation of a wealth of otherwise useless data, for to the writer's knowledge no other technique has been presented to date which makes direct use of this information for designing pipe lines.

An advantage of this method is that its applicability in problems involving fluids of high solids content has been proved, but conversely one of its limitations is believed to be that it is not yet applicable to relatively nonviscous non-Newtonian fluids of low solids content. Such fluids are frequently handled in the turbulent flow region to which these correlations have not been extended, or when they are in laminar flow, they tend to allow the solids to settle out, thereby again making the correlation inapplicable. For this reason the low-velocity, large-diameter pipe-line data on clay slurries presented by Wilhelm *et al.* (10) were not correlated in this manner. For the case of fluids exhibiting plastic behavior, however, the precise calculation of pressure drop due to turbulent flow in pipe lines has been treated elsewhere (5,7). Furthermore since turbulent flow is usually encountered only with slurries or fluids of low solids content, which are more nearly Newtonian, a special calculational technique is not so badly needed for this case.

Further work is needed to improve the method presented, particularly to make modifications which will reduce the amount of pipe-line data needed for predicting the pressure drops of new non-Newtonian fluids. Second, a means for predicting pressure drops in equipment other than pipe lines used to process viscous, non-Newtonian fluids is needed, and the applicability of the present approach to this problem should be determined.

In passing it may be noted that for Newtonian fluids $\Delta P_{calc.}/\Delta P_{actual}$ is constant at 1.0 for all values of V/nD . Therefore one may consider the calculation of pressure drop for Newtonians to be a special case of this present method in which the slope of the correlating line on a $\Delta P_{calc.}/\Delta P_{actual}$ vs. V/nD plot is zero.

As pointed out in a previous paper (1), the properties of non-Newtonian fluids depend appreciably on factors such as method and degree of dispersion and particle size. As a result, data obtained on a given fluid by one investigator are often not applicable to the work of another who does not, and frequently cannot, reproduce all these factors. Therefore no attempt has been made to present large quantities of data on various fluids; sufficient data have been presented to establish only the usefulness and generality of the method.

Summary

A new method for the correlation and prediction of the pressure-drop requirements for the flow of non-Newtonian fluids in pipe lines has been presented. Its development confirms the correctness of the initial hypothesis that laboratory viscosity determinations for these fluids

are not directly applicable to the design of pipe lines only because of the differences between the shear rate of the fluid in the laboratory determination on one hand and at the wall of the pipe on the other. The fields of application of this method are of three general types:

1. First, and probably most important, it may be used as a basis for the design of a model with which to predict the pressure-drop characteristics of a prototype. As such, it has all the advantages of the Theory of Models: a single determination on a convenient model under convenient conditions enables the prediction of the pressure drop in an unwieldy prototype. The criteria of model design are that it must have the same ratio of V/D as the prototype and the fluid properties must be the same as those to be encountered in the prototype. Since these criteria are adequate for plastic, pseudoplastic and dilatant non-Newtonians as well as for Newtonian fluids, it is not first necessary for purposes of proper model design and prototype construction for a new slurry of unknown characteristics to determine into which of these various categories the new slurry falls. However the absence of thixotropy or rheopexy should be proved by shearing the fluid isothermally for a period of time.

2. Laboratory data may be used directly to predict quantitatively the effect of changes in fluid properties on the pressure drop in a pipe line. Further these laboratory data may be obtained with the nonideal viscometers common to the field of non-Newtonian rheology since a detailed knowledge of the surface shear rates is not necessary.

3. Since the correlation is by means of dimensionless groups, limited plant data are readily extended and generalized. Such limited data on a pipe line are initially necessary, however, to establish the correlation for the particular fluid in question.

The correlating method has been applied under the following ranges of conditions to five different plastic and pseudoplastic slurries. The mean deviation of all the data from the correlating curves was only 11%.

PSEUDOPLASTICS

Three different aqueous synthetic detergent slurries

Solids content	53-59%
Temperatures	95°-161° F.
Nominal pipe size (diam.)	½, 2 and 3 in.
Apparent Reynolds No.	0.43-92.5
Viscometer	Brookfield viscometer, capable of measurements at 2, 4, 10 and 20 r.p.m.

PLASTICS

a. Cement-rock slurries (10)

Solids content	61.2 and 62.3%
Temperatures	79°-82° F.
Nominal pipe size (diam.)	¾ and 1½ in.
Apparent Reynolds No.	30-1910
Viscometer	Rotational viscometer, generally similar to the Interchemical (1)

b. Illinois-yellow-clay suspension (4)

Solids content	48%
Nominal pipe size (diam.)	3 in.
Apparent Reynolds No.	60-630
Modified Reynolds No.	106-4500
Viscometer	Pipe-line viscometer, with a pipe of unstated diameter

Acknowledgment

The author is indebted to the Colgate-Palmolive-Peet Co. for permission to publish this paper, and to the following engineers who obtained the company data reported herein: J. A. Monick, C. A. Martin and R. W. Holbrook. Brookfield Engineering Laboratories, Stoughton, Mass., supplied photographs of the Brookfield viscometer.

Notation

D = inside diameter of pipe, ft. or in. D_m refers to a model and D_p to a prototype

g_c = dimensional conversion factor, 32.2 ft. lb.-m./sec.² lb.-f.

l = length of pipe line, ft.

n = viscometer speed or shear rate. In calculations on Illinois-yellow-clay slurries taken as the true shear rate of the fluid (dv/dx), sec.⁻¹; in all other calculations, taken as the rotational speed of the viscometer, r.p.s.

N_{Re} = Reynolds number. For a Newtonian fluid $N_{Re} = DG/\mu$; for a non-Newtonian fluid the apparent Reynolds number is taken as DG/μ_a , and for a pure plastic fluid the modified Reynolds number is DG/η . It has been shown (5,7) that the modified Reynolds number alone is no criterion of the onset of turbulence, but it is believed that either a true or apparent Reynolds number of about 2100 does indicate the end of the stable laminar-flow region

ΔP = pressure drop, lb.-f./sq.ft., or lb.-f./sq. in. $\Delta P_{calc.}$ is obtained using μ_L or μ_a , the apparent viscosity of a non-Newtonian fluid as determined with a laboratory viscometer. ΔP_{actual}

is the actual pressure drop due to flow of a fluid through a pipe

v = local velocity, ft./sec.

V = average linear velocity, or bulk velocity, of fluid in a pipe, ft./sec.

x = linear distance in a direction perpendicular to the shear planes, ft.

η = coefficient of rigidity of a pure plastic non-Newtonian fluid, lb.-m./sec.ft. (η = slope of line BD in Figure 1, multiplied by g_c)

τ = shear stress, lb.-f./sq.ft.

τ_y = yield strength of a pure plastic non-Newtonian fluid, lb.-f./sq.ft. (distance OB in Figure 1)

μ = viscosity of a Newtonian fluid, lb.-m./sec.ft. μ_a is the actual apparent viscosity of a non-Newtonian fluid; μ_L is the apparent viscosity of a non-Newtonian fluid as determined with a laboratory viscometer; if the viscometer used was a Brookfield unit, μ_a was used in place of μ_L . For the Illinois-yellow-clay slurries μ_L was calculated by means of the following equation for plastic fluids:

$$\mu_L = \tau_y g_c / n + \eta$$

where

$$\tau_y = 0.72 \text{ lb.-f./sq.ft.}$$

$$\eta = 0.028 \text{ lb.-m./sec.ft.}$$

τ_y and η were obtained from pipe-line data in this case

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Presented at A.I.Ch.E. Biloxi meeting.

KINETICS OF THE CATALYTIC CRACKING OF ALKYL BENZENES

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The purpose of this investigation was to determine quantitatively the effect of molecular structure on the rate of catalytic cracking of mono-alkylbenzenes over a silica-alumina catalyst. This reaction was chosen because of the absence of complicating side reactions. Eight benzene derivatives were studied, namely, ethyl, *n*-propyl, *n*-butyl, *iso*-propyl, *sec*-butyl, *sec*-amyl, *tert*-butyl, and *tert*-amylbenzene.

Apparent Mechanism and Rate Equation

The apparent controlling kinetic mechanism for the cracking of cumene (*iso*-propylbenzene) over silica-alumina catalyst was shown to be a single-site surface reaction (5). Similarly (15) it has been shown that the cracking of *sec*-amylbenzene follows the same mechanism. Results presented in this paper have been calculated on the assumption that other alkylbenzenes crack by this same mechanism:

adsorbed alkylbenzene \rightarrow adsorbed benzene + olefin.

This assumption permits the calculation of rate constants from a minimum of experimental data. This is highly desirable, considering the large amount of experimental data needed to establish completely the mechanism and rate equation for a particular reaction, and also the price of some of these compounds (e.g., \$287/gal.).

The rate equation for this type of reaction is as follows:

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This paper reports results of cracking eight mono-alkylbenzenes (ethyl, *n*-propyl, *n*-butyl, *i*-propyl, *sec*-butyl, *sec*-amyl, *tert*-butyl, and *tert*-amylbenzene) over silica-alumina catalyst. Data for conversion vs. reciprocal space velocity curves were obtained at 850, 950, and, 1,050° F. Data were correlated on the basis of a single-site, surface-reaction controlling.

It was found that the enthalpy of activation for these compounds was constant. The kinetic velocity constant ELk correlated with the over-all entropy change for the reaction; the alkylbenzene adsorption constant K_A at 950° F. was shown to correlate with the strength of the bond joining the alkyl group to the benzene nucleus. The benzene adsorption constant K_R was constant for all compounds investigated. These constants are reported as functions of temperature. Data are also presented for coke formation on the catalyst.

$$r = \frac{ELkK_A \left(p_A - \frac{p_R p_B}{K} \right)}{1 + K_A p_A + K_R p_R} \quad (1)$$

where

E = effectiveness factor

L = number of molal active sites per unit mass

k = reaction velocity constant

K_A = adsorption constant for alkylbenzene (A)

K_R = adsorption constant for benzene (R)

K = equilibrium constant for over-all reaction

r = moles A converted/(mass of catalyst) (time)

p_A = partial pressure of alkylbenzene (A)

p_R = partial pressure of benzene (R)

p_B = partial pressure of olefin corresponding to component A

The integrated equation in terms of reciprocal space velocity (W/F) is

$$\frac{W}{F} = \gamma \left[\left(\frac{1}{2\delta} - \frac{1}{2\delta^3} \right) \ln \left(\frac{1+\delta x}{1-\delta x} \right) + \frac{x}{\delta^2} \right] + \beta \left[\frac{1}{2\delta^3} \ln \left(\frac{1+\delta x}{1-\delta x} \right) - \frac{1}{2\delta^2} \ln (1 - \delta^2 x^2) - \frac{x}{\delta^2} \right] \quad (2)$$

where

γ and β are convenient groupings of adsorption and velocity constants

$$\gamma = \frac{1}{ELkK_A\pi} + \frac{1}{ELk}$$

$$\beta = \frac{2}{ELkK_A\pi} + \frac{K_R}{ELkK_A}$$

π = total pressure

x = conversion

$$\delta = \frac{1}{x^*} = \sqrt{1 + \frac{\pi}{K}}$$

in which

x^* = equilibrium conversion

K = thermodynamic equilibrium constant for over-all reaction

Where the reverse reaction is negligible

ible Equation (2) becomes much simplified, thus,

$$\frac{W}{F} = \gamma x - \beta [-\ln(1-x) - x] \quad (3)$$

Carbonium Ion Theory of Reaction

Thomas *et al.* (25) and Greensfelder *et al.* (11) have studied the catalytic cracking of various *mono*-alkylbenzenes over silica-alumina catalyst and have found striking changes in the "ease of cracking" with variations in the alkyl side chain. Product distributions were reported and data sufficient for qualitative comparisons between compounds were obtained. These investigators proposed an explanation of cracking based on the carbonium ion theory. It is now generally accepted (10, 12, 17, 23, 24) that silica-alumina catalyst possesses acid properties or potential acidic properties which enable it to act as an electron pair acceptor (Lewis Acid) and a proton donor.

The derivation of Equation (1) is based on the postulation that the reaction takes place by the following steps (13):

1. Activated adsorption of the alkylbenzene
2. Surface reaction of adsorbed alkylbenzene \rightarrow adsorbed benzene + olefin

3. Desorption of benzene

This agrees with the carbonium ion mechanism originally suggested by Thomas (25), which in the light of the latest concepts of the nature of silica-alumina catalysts (17) would appear to be as shown below under Steps 1 and 2 (where *R* represents the alkyl group).

The benzene is subsequently desorbed, and the alkyl carbonium ion rapidly expels a proton to form an olefin. The carbonium ion theory does not require that the olefin or alkyl group be adsorbed at any stage in the reaction, thus agreeing with the results of Corrigan (5) and Johnson (15).

The carbonium ion theory further justifies the assumption that all *mono*-alkylbenzenes crack by the same mechanism.

The rate of the surface reaction depends on the ease of formation of the alkyl carbonium ion, and it is well known (1, 27) that the order of stability and thus ease of formation of the alkyl carbonium ions is tertiary > secondary > primary. This stability is explained by hyperconjugative resonance (1). *Tert*-butyl carbonium ion can assume nine forms; *iso*-propyl, seven; and ethyl, three. The inductive effect or electron repelling

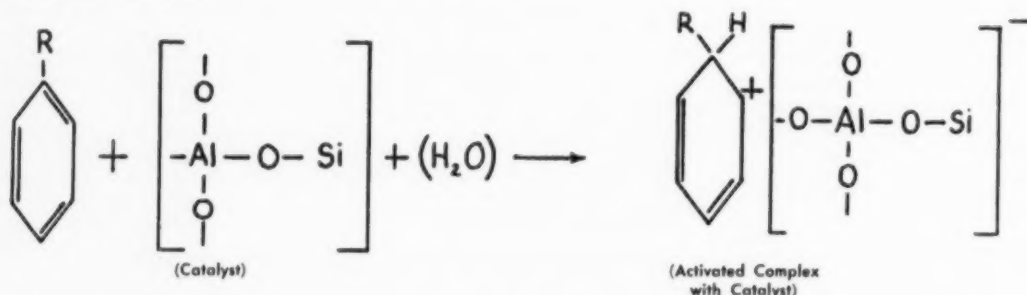
tendency of alkyl groups follows the order tertiary > secondary > primary (*n*-butyl > *n*-propyl > ethyl > methyl). As this electron repelling tendency increases, the strength of attachment of the alkyl group decreases. The inductive effect, therefore, supplements that of hyperconjugative resonance in determining the ease of carbonium ion formation. The inductive effect alone must be used, however, to explain the differences in reactivity of the normal compounds since resonance possibilities are approximately the same for all members of this group. The differences between successive compounds in the normal series become smaller as the chain length increases because the point of replacement of H by CH_3 recedes from the carbon attached to the benzene ring. In a homologous series of *n*-alkyl compounds it is, therefore, common for a constant "reactivity" to be reached early in the series.

Experimental Procedure

The apparatus used in this study was the same as that described by Corrigan, Garver, Rose, and Kirk (5). A flow diagram is given in Figure 1.

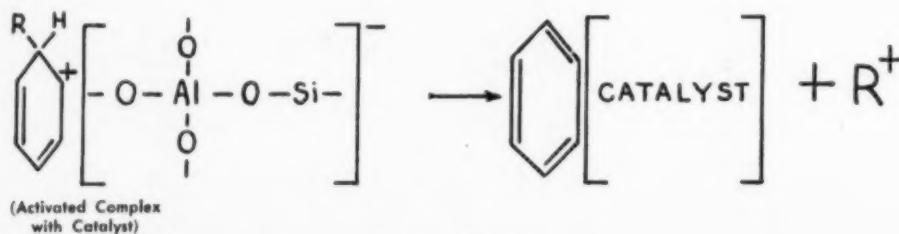
Catalytic runs were of fifteen-minute duration, the fifteen-minute period being started

Step 1—Activated Adsorption



(The water furnishes the hydrogen proton for the reaction and may come from the catalyst or may be present in the feed in trace quantities.)

Step 2—Surface Reaction



five minutes after the appearance of the first liquid in the condenser. The liquid collected in the first five minutes was discarded since it was previously shown (4) that conversion reached a relatively constant value after this initial period. Observations of feed tank level and wet test meter readings were made every two minutes. Liquid product was removed at the end of each run, weighed, and immediately placed under refrigeration. The reactor was purged with nitrogen for fifteen minutes following each run, and then the catalyst was regenerated with air for one-half hour. Fresh catalyst was charged for each compound tested.

In order to obtain data in the low conversion range it was necessary, because of condenser and preheater limitations, to reduce the quantity of catalyst from five to two grams for some of the more reactive compounds. This quantity of catalyst produced a bed of only one bead thickness and conversion results were low compared to those obtained at the same W/F using five grams of catalyst. Since the flow patterns were probably different and considerable by-passing was occurring, Pyrex glass beads of the same diameter as the catalyst beads were mixed with the catalyst to give a total bed volume equal to that of five grams of catalyst. Results with this mixture were in line with those previously obtained with five grams of catalyst. The glass beads showed no catalytic activity.

Frequent material balances were made; the maximum deviation from 100% was found to be 3%, with an average deviation of 1%.

The homogeneous reaction was tested for each compound by replacing the catalyst with an equivalent amount of inert quartz chips and following the same technique as used in the catalytic experiments.

Feed Stocks

All feed stocks regardless of the purity stated by the manufacturer were redistilled in a 30-plate (26 mm. diam.) Oldershaw distillation column at 20:1 reflux ratio. The feed thus purified was checked for additional impurities by means of differential infrared spectrum analysis using specially purified samples as standards. Where feasible, materials from several sources were used in the cracking experiments to provide a check against possible undesirable trace impurities which could affect the catalyst activity. Properties and sources of the alkylbenzenes used in this work follow. Unless otherwise stated, infrared analysis of redistilled feed showed no detectable impurities.

ethylbenzene: Distillation Products 134-136°C. boiling range, 1.4865 n_D^{20} . Discarded first and final 10% of Oldershaw overhead product.

n-propylbenzene: Distillation Products 153-157°C. boiling range. Discarded first and final 10% of Oldershaw overhead product.

iso-propylbenzene: sample No. 1—Distillation Products 150-152°C. boiling range, 1.493 n_D^{20} . Discarded first 18% and final 14% of Oldershaw overhead product. Sample No. 2—Dow Chemical Co. Discarded first and final 15% of

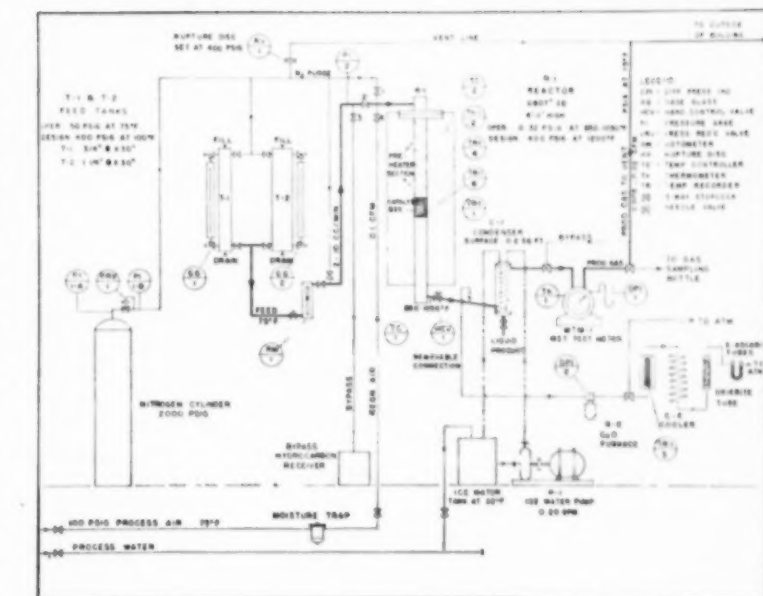


Fig. 1. Flow diagram.

Oldershaw overhead product. Infrared spectra for Samples No. 1 and 2 identical.

n-butylbenzene: Phillips Petroleum Co. specified as 95% pure. Discarded first and final 10%.

sec-butylbenzene: Phillips Petroleum Co. 99% pure, B.P. = 173.5°C., 1.490 n_D^{20} , principal impurities other alkylbenzenes and organic fluorides. Discarded first 2% and final 8% of Oldershaw overhead product.

tert-butylbenzene: Sample No. 1—Sharples Chemical, Inc. 0.866 sp. gr. @ 20°C.; Engler distillation: I.B.P. = 166°C., 50% = 168.7, F.P. = 172.5°C. Discarded first 7% and final 16% of Oldershaw overhead product. Infrared showed trace impurity, probably a carbonyl compound.

Sample No. 2—Phillips Petroleum Co. 99% pure, B.P. = 169.2°C.; most probable impurities are other alkylbenzenes, 1.492 n_D^{20} . Discarded first 2% and final 7% of overhead product.

sec-amylbenzene: Distillation Products 2-phenyl pentane, specified as 188-191°C. boiling range. Discarded first and final 10% of overhead product. Infrared analysis and Podbielniak analytical distillation indicated presence of small amounts of other C_6 alkylbenzenes.

tert-amylbenzene: Distillation Products 188-191°C. boiling range. Discarded first 8% and final 15% of overhead product.

Analytical Methods

To insure accurate analytical results, each sample was analyzed by two independent methods, distillation and infrared absorption. Since the conversion is defined as the moles of benzene formed per mole of original feed, the conversion can be determined from the quantity of benzene in the liquid product assuming all heavier material to be unreacted

alkylbenzene. At low conversions the quantity of polymer and other side reaction products is negligible. Bromine number determinations on the heavier than benzene fraction of the liquid product indicated that unsaturates were present in only negligible amounts.

Analytical distillations were made on a standard Podbielniak 13 mm. I.D. \times 36-in. long Heli-Grid, Hyper-Col distillation column using ice water as the condenser coolant. Synthetic samples were prepared for each system and used to establish empirical cut-points.

A Baird recording infrared spectrophotometer with a NaCl prism was used for the infrared survey work and in checking for interferences. The quantitative infrared analyses were made, using a Beckman spectrophotometer with a NaCl prism. A benzene absorption peak of 14.86 μ was employed.

The optical densities of the samples were referred to that of the alkylbenzene. A calibration curve of optical density vs. weight per cent benzene was obtained, using synthetic mixtures of benzene in the alkylbenzene diluent. In order to achieve maximum accuracy, all samples were diluted to below 3% benzene by weight, the region of maximum slope of the optical density curve.

Surprisingly good agreement (0.5% deviation) between the distillation and infrared analyses was obtained even in the low conversion range. The infrared analysis was relied upon strongly at low conversions because the percentage error was independent of benzene concentration. The distillation error, however, was absolute and accordingly, the percentage error increased with decreasing conversion.

Catalyst and Catalyst Activity

The catalyst used was a T.C.C. silica-alumina bead cracking catalyst and was taken from the same batch as that used for the previous investigations on cumene (5) and *sec*-amylbenzene (15). A -5 + 6 mesh fraction was used from which all broken and irregular particles were removed. The beads approximated spheres of an average diameter of 0.398 cm. [bulk density = 0.685 g./cc., particle density = 1.149 g./cc., real density = 2.37 g./cc., effectiveness factor = 0.16 (5)]. Because of the low effectiveness factor exhibited by this catalyst (5) and large dependence of "activity" on particle size, care in obtaining uniform particles was observed.

An extensive activity study using *iso*-propylbenzene showed the catalyst activity to be essentially constant over thirty cycles, even including the initial run with the fresh catalyst. As an additional check the first run on each compound was repeated at the end of each series. No significant change in activity was detected.

Homogeneous Reaction

In all cases except runs with *tert*-butylbenzene and *iso*-propylbenzene at 1,050° F., the homogeneous reaction was found to be negligible. Homogeneous conversion was as high as 3% for *tert*-butylbenzene at 1,050° F. Since this conversion must be subtracted from the over-all conversion to obtain the catalytic conversion, additional uncertainties are introduced, which should be avoided in such a study. Temperatures below 1,050° F., therefore, were used on all other compounds except ethylbenzene which did not exhibit a significant homogeneous reaction even at 1,050° F.

CALCULATION OF CONSTANTS OF THE RATE EQUATION

Although calculation of the rate equation constants from the integrated equation by the method of least mean squares is one of the more generally accepted methods, such an approach was not practical in this investigation because of the relatively small amount of data obtained on the more costly compounds. If Equation (1) is written for the initial rate r_0 , it reduces to a form having only two unknowns, ELk and K_A .

$$r_0 = \frac{ELk K_A \pi}{1 + K_A \pi} \quad (4)$$

These two constants thus may be determined directly from initial rates obtained at two different pressures. The principal difficulty in this method is obtaining reliable values of r_0 , which is the slope at the origin of the x vs. W/F curve. It is possible, however, to over-

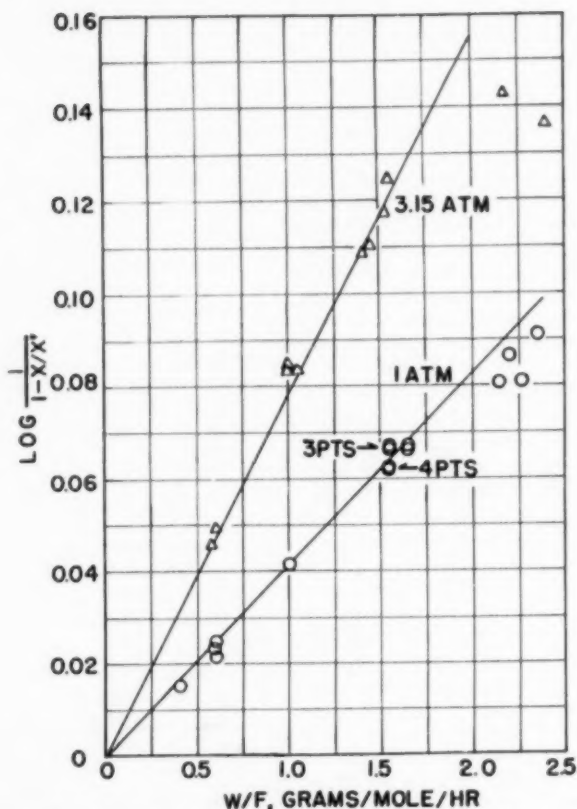


Fig. 2. Pseudo-first-order plot for *iso*-propylbenzene at 950° F.

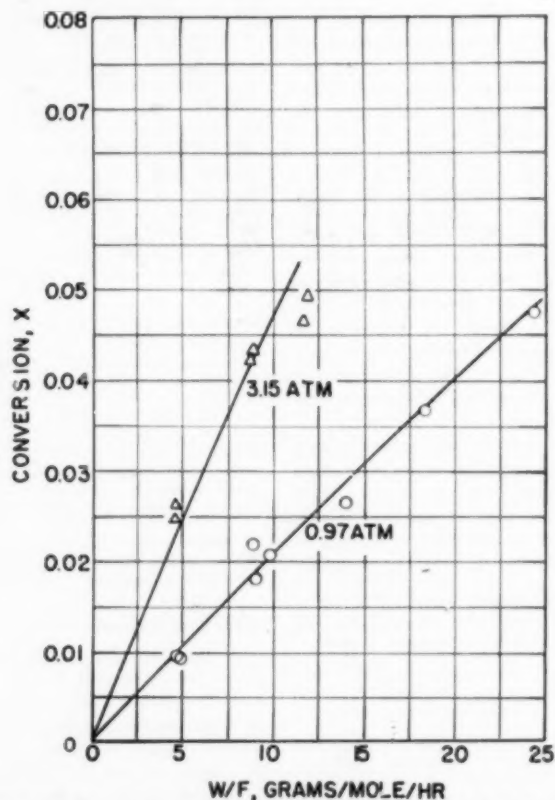


Fig. 3. Comparison of experimental data and calculated X vs. W/F curve for ethylbenzene at 950° F.

come this difficulty by employing the pseudo-first-order assumption, suggested by Hougen and Watson (13), which states that even complex catalytic reactions approximate first-order behavior at constant pressure and low conversions, where the effects of reaction products are negligible. The integrated equation based on the pseudo-first-order assumption is

$$W/F = \frac{x^*}{r_0} \ln \frac{1}{1 - \frac{x}{x^*}}$$

where x^* = equilibrium conversion.

If, therefore, $\ln [1/(1 - x/x^*)]$ in the low-conversion range is plotted vs. W/F , a straight line passing through the origin is obtained, the slope of which equals x^*/r_0 . This method was used to obtain r_0 at two different pressures for calculation of ELk and K_A . Low-conversion data were emphasized because of the greater validity of the assumption in this range and the absence of side reactions and attendant complexities.

Figure 2 is typical of the pseudo-first-order curves obtained in this work. Where points scattered somewhat in the low-conversion range, the best straight line was obtained by the method of least percentage difference squared (16) in order to give equal weight to all points in the low-conversion range.

Having calculated ELk and K_A , K_R was obtained from Equation (3) by plotting $[W/F - \gamma x]$ vs. $[-\ln(1 - x)$

$-x]$. A straight line of slope β was obtained from which K_R could be calculated.

The most suitable test of the accuracy of these constants is to use them in calculating an x vs. W/F curve for comparison with the experimental data. This was done for the compounds for which sufficient data had been obtained to justify such a procedure (ethylbenzene, *iso*-propylbenzene, *tert*-butylbenzene, and *sec*-amylbenzene). The curves for ethylbenzene are presented in Figure 3. The other data showed similar agreement. Since the comparison was satisfactory it was assumed that the method for obtaining constants was equally applicable to the other compounds.

It can be shown mathematically that in the determination of ELk and K_A from initial rates, K_A is more sensitive to changes in the initial rate than ELk , while K_R is even more sensitive. The maximum probable errors were estimated as 5% for ELk , 15% for K_A , and 15-50% for K_R . These are rough estimates and it is believed that the relative consistency between values for a single compound is better.

Reaction Velocity Constant ELk

The relation of the reaction velocity constant to temperature can be expressed by either the Arrhenius concept Equation (5) or the Theory of Absolute Reaction Rates Equation (6).

$$\ln k = \ln (PZ) - \frac{\Delta H^\ddagger}{RT} \quad (5)$$

$$\begin{aligned} \ln k &= \ln \frac{\bar{k}}{h'} + \ln T - \frac{\Delta G^\ddagger}{RT} \\ &= \left[\ln \frac{\bar{k}}{h'} + \frac{\Delta S^\ddagger}{R} + \ln T \right] - \frac{\Delta H^\ddagger}{RT} \end{aligned} \quad (6)$$

where:

T = absolute temperature

Z = collision number

P = probability or steric factor

\bar{k} = Boltzman constant

h' = Planck's constant

ΔG^\ddagger = free energy accompanying the formation of activated complex

ΔH^\ddagger = enthalpy of activation

ΔS^\ddagger = entropy of activation

Since ΔS^\ddagger and ΔH^\ddagger are usually constant over the average range of cracking temperatures and the term $\ln T$ is usually small compared to $\Delta H^\ddagger/RT$, a straight line of slope $\Delta H^\ddagger/R$ will ordinarily be obtained by plotting $\ln k$ vs. $1/T$. Since this straight-line assumption is generally made in engineering studies, it is more convenient to employ the simpler Arrhenius form, calling PZ equivalent to

$$\left[\ln \frac{\bar{k}}{h'} + \frac{\Delta S^\ddagger}{R} + \ln T \right].$$

It is desirable, however, for purposes of theoretical considerations to understand the exact relation between PZ and the more basic entropy of activation. This relation can be obtained by comparing the value of $\ln k_a - \ln k_b$ from Equations (5) and (6), where a and b refer to different compounds reacting at the same temperature.

$$\begin{aligned} \ln k_a - \ln k_b &= \ln (P_a Z_a) - \ln (P_b Z_b) \\ &= \frac{\Delta S_a^\ddagger}{R} - \frac{\Delta S_b^\ddagger}{R} \end{aligned}$$

or

$$R \ln \frac{P_a Z_a}{P_b Z_b} = \Delta S_a^\ddagger - \Delta S_b^\ddagger \quad (7)$$

Plots of $\log ELk$ vs. $1/T$ for the eight *mono*-alkylbenzenes studied are presented in Figure 4. The constancy of the slopes and thus ΔH^\ddagger for the various compounds is most striking. This is also shown in Table I where values of ΔH^\ddagger calculated from large-scale plots are recorded, together with the standard heats of reaction at 298°K., and the ratio $\Delta H^\ddagger/\Delta H^\circ$. If ΔH^\ddagger is a constant value for all *mono*-alkylbenzenes, then the large variation in ELk must be caused by variations in the entropy (ΔS^\ddagger) or PZ term.

The activated complex represents a state of maximum free energy during a reaction ($\Delta G^\ddagger = \Delta H^\ddagger - T\Delta S^\ddagger$). When

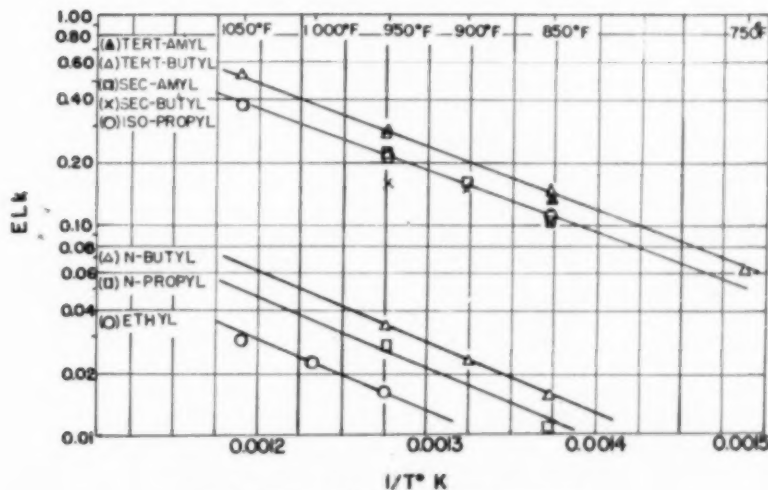


Fig. 4. Reaction velocity constant vs. temperature.

Table 1.—Experimental Enthalpies of Activation for Eight Alkylbenzenes

Compound	ΔH^\ddagger		ΔH° ²
	K cal./g. mole	Reaction of K cal./g. mole	
Ethylbenzene ...	15.2	25.2	0.60
N-Propylbenzene (15.0) ¹	15.0	22.8	...
Iso-Propylbenzene	13.2	23.8	0.58
N-Butylbenzene	15.0	23.4	0.64
Sec-Butylbenzene (13.2) ²	13.2	22.9	...
Tert-Butylbenzene	14.8	21.9	0.68
Sec-Amylbenzene	14.0	22.7	0.62
Tert-Amylbenzene (14.8) ²	14.8	20.9	...
Avg.	14.4	...	0.62

¹ Values in parentheses based to large extent on results for other compounds for which extensive data were taken.

² Calculated from (21). Heats of formation for the two amylbenzenes and sec- and tert-butyl based on Prosen (20) since consistent with API 44 (21).

comparing two reactions *a* and *b*; therefore, the difference in the free energies of activation can be represented by a difference in enthalpy of activation if ΔS^\ddagger is constant ($\Delta G_a^\ddagger - \Delta G_b^\ddagger = \Delta H_a^\ddagger - \Delta H_b^\ddagger$) or as a difference in entropy of activation if ΔH^\ddagger is constant, as in this study, ($\Delta G_a^\ddagger - \Delta G_b^\ddagger = \Delta S_a^\ddagger - \Delta S_b^\ddagger$).

Polanyi and his associates (2, 3, 6, 9, 18) proved that for a series of analogous homogeneous ionic reactions of alkyl halides ($R-X$) in which *PZ* or ΔS^\ddagger remained constant with changes in *R*, the enthalpy of activation decreased proportionally as ΔH° (heat of reaction) increased

$$(\Delta H_a^\ddagger - \Delta H_b^\ddagger = -a[\Delta H_a^\circ - \Delta H_b^\circ]).$$

For the catalytic cracking of alkylbenzenes, where ΔS^\ddagger varies and ΔH^\ddagger is constant, it may be reasoned that changes in ΔS^\ddagger should be proportional to changes in ΔS° , thus

$$\Delta S_a^\ddagger - \Delta S_b^\ddagger = a(\Delta S_a^\circ - \Delta S_b^\circ)$$

or

$$R \ln \frac{P_a Z_a}{P_b Z_b} = a(\Delta S_a^\circ - \Delta S_b^\circ) \quad (8)$$

(See Fig. 5.) This concept, though oversimplified here, is not entirely foreign to the thinking of physical chemists. Several investigators (7, 8, 14, 19, 28) have presented data on series of non-catalytic reactions in which the entropy or *PZ* factor caused the significant variations in the reaction velocity constant while variations in ΔH^\ddagger were relatively insignificant.

In Figure 6 the relationship postulated in Equation (8) is plotted for the eight compounds studied using ethylbenzene as the reference, and ΔS° values at 298° K. Tabulated values are presented in Table 2. The plot emphasizes several remarkable findings.

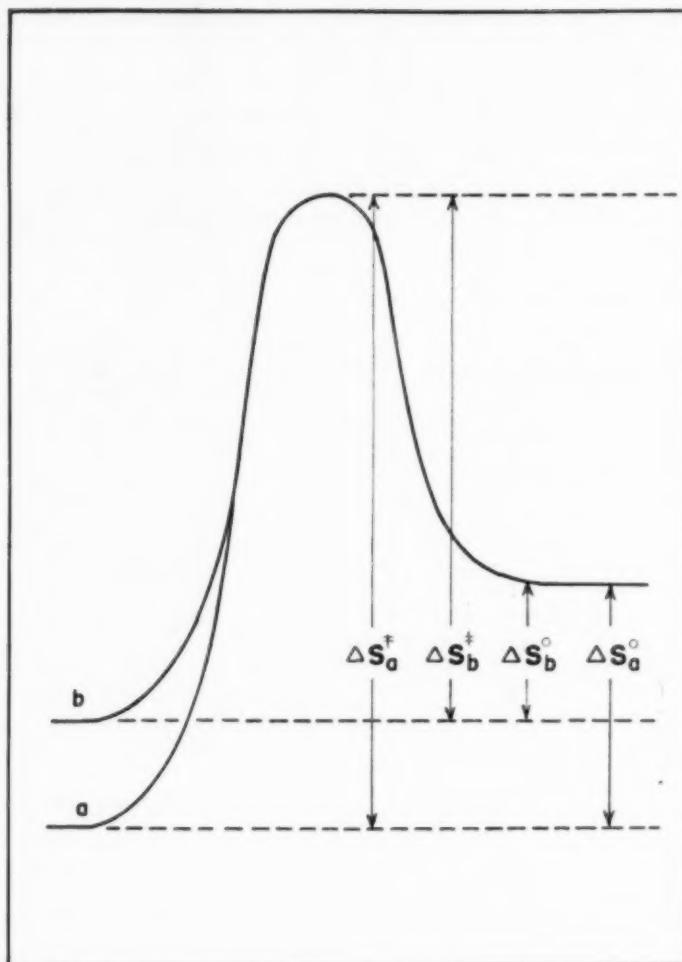


Fig. 5. Entropy of activation changes in catalytic cracking.

Table 2.—*PZ* Factors for Catalytic Cracking of Eight Alkylbenzenes

Basis: ΔH^\ddagger constant at 14.4 K cal./g. mole

Compound	ΔS° of Reaction (at 25° C.)	ΔS_a° — ΔS_b°	ΔS_a^\ddagger — ΔS_b^\ddagger	<i>PZ</i>	$\log \frac{P_a Z_a}{P_b Z_b}$
Ethylbenzene	30.64	0	0	5.12	0
N-Propylbenzene	32.40	1.76	0.886	5.57	0.036
N-Butylbenzene	32.91	2.27	1.47	5.81	0.055
N-Amylbenzene	33.33	2.69	...	...	...
N-Hexylbenzene	33.31	2.67	...	...	...
N-Heptylbenzene	33.31	2.67	...	...	...
Iso-Propylbenzene	35.27	4.63	5.14	7.70	0.178
Sec-Butylbenzene	34.93	4.29	5.14	7.70	0.178
Sec-Amylbenzene	35.43	4.79	5.20	7.72	0.179
Tert-Butylbenzene	38.21	7.57	5.72	7.97	0.192
Tert-Amylbenzene	37.71	7.07	5.62	7.96	0.191

* All values from Rossini (21) except last four which were calculated by method suggested by (20). Calculations were made by C. F. Curtiss and R. B. Bird of Univ. of Wis.

ΔS° = entropy change for over-all reaction

ΔS^\ddagger = entropy of activation

PZ = Arrhenius intercept, temperature independent factor

a = any alkylbenzene

b = ethylbenzene

1. PZ factors for secondary alkylbenzenes are essentially constant at 7.71.
2. PZ factors for tertiary alkylbenzenes are essentially constant at 7.95.
3. Variation in PZ factor for the normal alkylbenzenes follows the relationship $\log P_a Z_a / P_b Z_b = 0.0225 (\Delta S_a^\circ - \Delta S_b^\circ)$. $\Delta S_a^\circ - \Delta S_b^\circ$ becomes constant above C_5 and thus the curve terminates at this point. This is in agreement with the interpretations of the inductive effect with respect to n -alkyl groups as discussed previously.
4. The sequence of reactivity of tertiary > secondary > primary predicted by the carbonium ion theory is followed in these results and has here been given quantitative expression.

It cannot be said that secondary and tertiary compounds fall on the same line as the primary, although this might be true if more accurate values of entropies were available. In dealing in differences of ΔS° values, the absolute error may be large even though the percentage error of the individual thermodynamic data may be small. Perhaps a better correlation might result using ΔS° at the temperature of the reaction, but unfortunately the absolute uncertainties in the ΔS° values at these higher temperatures are even greater.

In calculating ΔS° for reactions in which several isomeric olefins are possible, the relative amounts of isomers were determined from thermodynamic equilibria for those isomers which could be formed from the original carbonium ion without rearrangement. This is justified since only the primary reaction is of interest in a kinetic study of this nature.

Benzene Adsorption Constant K_R

The variation of the constant K_R for benzene from compound to compound was found to be sufficiently random and of such magnitude that the value of K_R can be considered, within the experimental error, to be the same for all the mono-alkylbenzene reactions as shown in Table 3. This further verifies that cracking of alkylbenzenes takes place by a single-site mechanism—benzene is chemisorbed, but the olefin is not adsorbed as a step in the catalytic cracking reaction. It may, however, be subsequently adsorbed.

Reactant Adsorption Constant K_A

Although values of K_A were determined from the original initial rate data, as have been described, recalculation of K_A using the average values of K_R from Table 3 in the integrated equation produced slightly more consistent and pre-

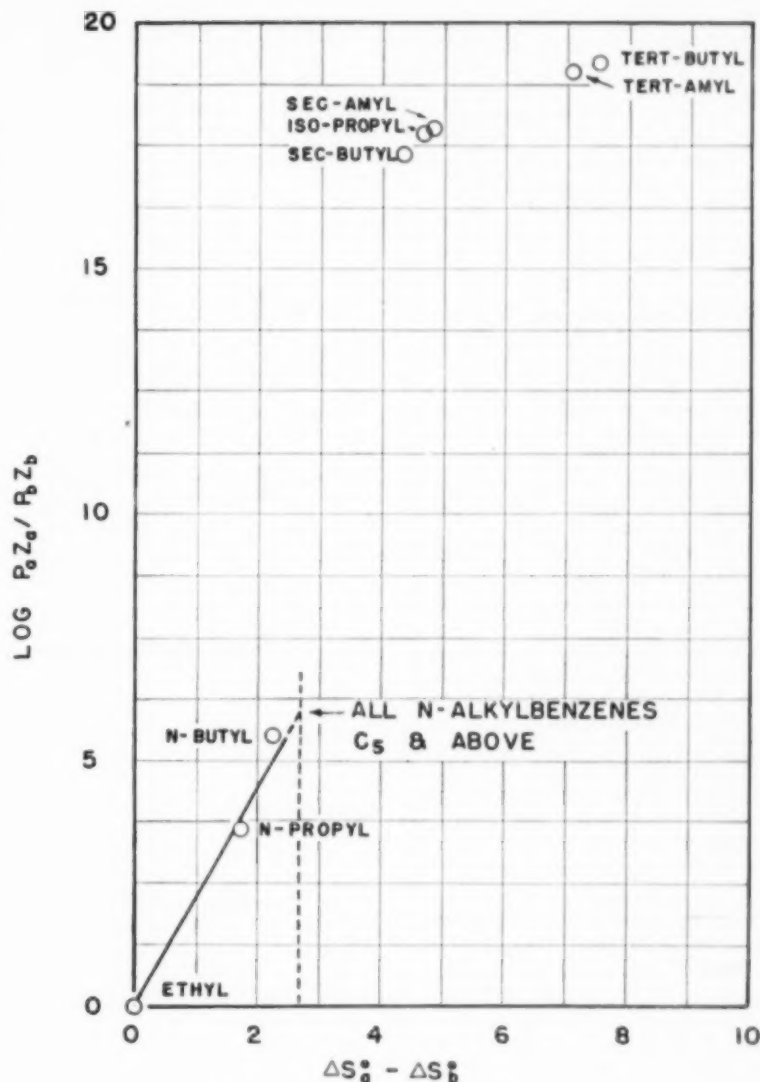


Fig. 6. $\log P_a Z_a / P_b Z_b$ vs. $\Delta S_a^\circ - \Delta S_b^\circ$.

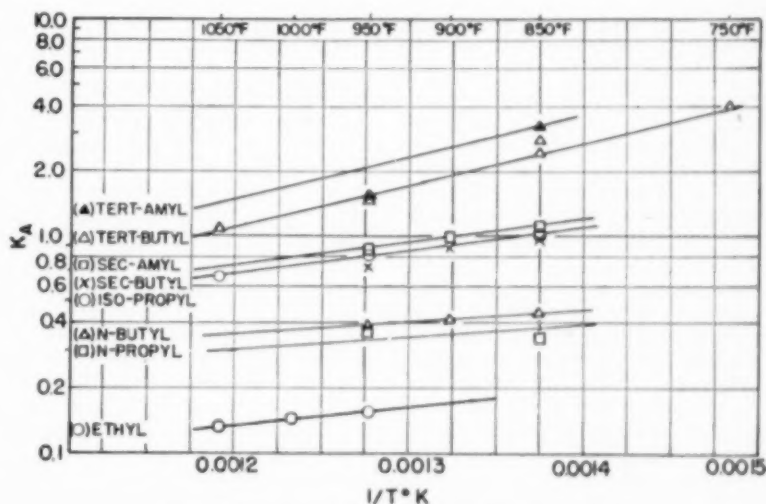


Fig. 7. Alkylbenzene adsorption constant vs. temperature.

sumably more reliable data. These recalculated values are plotted in Figure 7. The slopes of these $\log K_A$ vs. $1/T$ lines cannot be said to be equal although equality appears to some extent in the various groups. Here again, however, the significant change in K_A with structure appears to be primarily a change in the entropy term for chemisorption

$$\ln K_A = \frac{\Delta S_A}{R} - \frac{\Delta H_A}{RT}$$

These so-called adsorption equilibrium constants, however, are empirical constants related to adsorption, and it does not seem possible in the present state of knowledge to attempt a correlation based on thermodynamically significant quantities such as ΔS_A and ΔH_A ; rather, would it be more appropriate to obtain an empirical correlation. Such a correlation is presented in Figure 8, where $\log K_A$ at 950° F. is plotted against the relative bond strength of $R-CH_3$ (where R is an alkyl group) determined from kinetic data (3). The bond strength of CH_3-CH_3 was taken as a base. Reasonable estimates of K_A at other temperatures can be made by assuming an average value of ΔH_A .

The activated adsorption step described previously involved the chemisorption of the alkylbenzene to form an alkylbenzene carbonium ion in intimate association with the catalyst. The relative stability of this complex, which de-

Table 3.—Adsorption Constant— K_A

Compound	Values from Curve		
	Temperature, °F.		
	850	950	1050
Ethylbenzene	3.8	2.80	2.1
Tert-Butylbenzene	2.9	2.25	1.7
Tert-Amylbenzene	2.1	1.70	1.4
Iso-Propylbenzene	1.8	1.43	1.2
Sec-Amylbenzene	1.5	1.15	0.96
Avg.	2.45	1.86	1.47

pends on the ability of the benzene nucleus to attract and hold a proton, should indicate the relative magnitude of the chemisorption equilibrium constant.

The electron repelling or releasing tendency of the alkyl carbon increases in the order ethyl < *n*-propyl < *n*-butyl < *iso*-propyl < *sec*-butyl < *sec*-amyl < *tert*-butyl < *tert*-amyl, and thus the benzene nucleus of the alkylbenzene increases in "electronegativity," or in the ability to attract and hold a proton, in the same order. This increasing electron release has an opposite effect on the bond strength. It is, therefore, reasonable

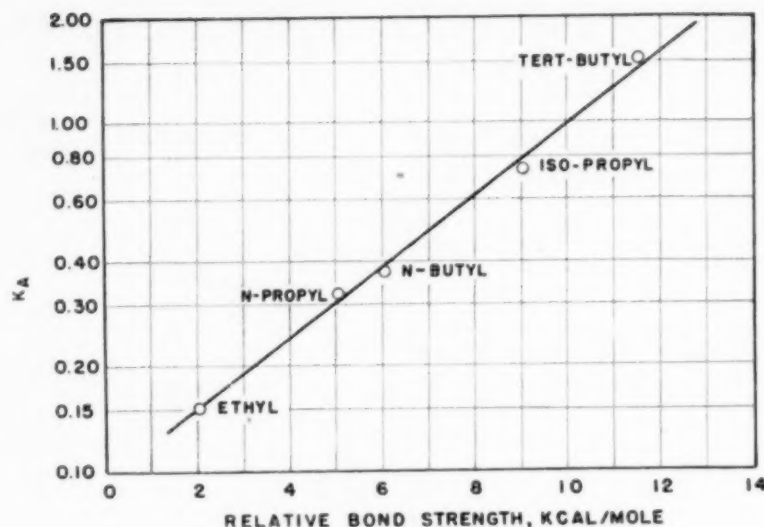


Fig. 8. Log K_A at 950° F. vs. relative bond strength.

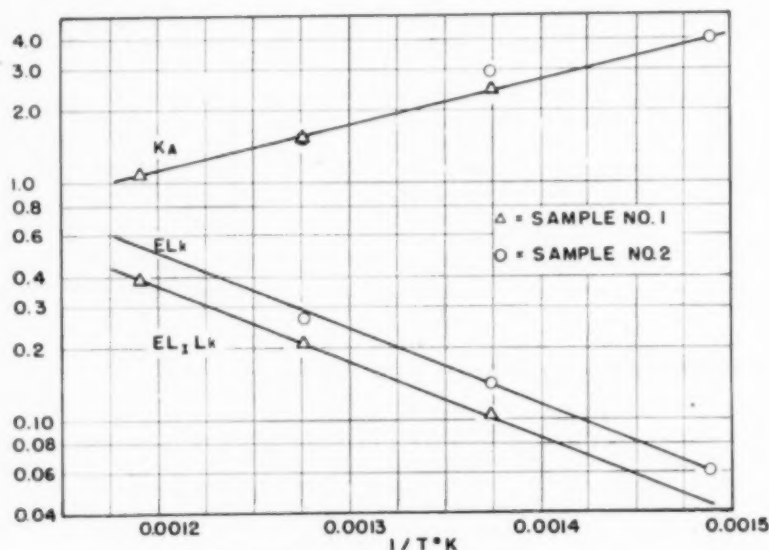


Fig. 9. Effect of impurity on rate constants.

that an empirical correlation should be obtained between the adsorption constant and the relative bond strength referred to methyl.

Unfortunately, comparable bond strength data for *sec*-butyl and amyl and *tert*-amyl are not available. It is believed, however, that these values will be close to those for *iso*-propyl and *tert*-

butyl respectively, and thus not materially disturb the correlation.

Effect of Impurities

An interesting example of the effect of a trace impurity which is apparently adsorbed strongly enough to cause competition for active sites between the impurity and the alkylbenzene

is presented in Figure 9. Plots for ELk and K_A represent values determined for *tert*-butylbenzene samples No. 1 and No. 2. Sample No. 1 contained a trace impurity which was identified as a probable carbonyl compound.

The ELk curve for the impure material is displaced below, but is parallel to that for the pure material. Values for K_A calculated from data for both materials fall essentially on the same line. This indicates that the impurity acts as a poison decreasing the number of active sites available for the primary reaction but does not affect the adsorption constant of the pure compound. It therefore has the effect of a reduction in activity which can be restored by regeneration.

This suggests that the catalyst-activity factor (13) may be applied to a method for developing rate equations for impure compounds when that for the pure compound is known. Constants for the pure compound can be used, and experimental work done with the impure compound only to the extent of an activity study. This would involve several runs at one temperature so that the values of W/F of pure and impure compounds can be compared at the same conversion. The ratio of values of W/F at equal conversion,

$$\frac{(W/F)_P}{(W/F)_I} = L_I$$

where

P = pure compound

I = impure compound

gives the multiplying factor L_I to be used in the numerator of the rate equation for the pure compound in order to calculate rates for the impure compound. L_I can be thought of as the per cent of active sites not covered by impurity. It is possible that much of the difficulty in correlating catalytic cracking data on pure compounds in the past has been due to the presence of impurities ordinarily overlooked but which were extremely significant because of their affinity for active sites.

Discussion of Cumene Results

Values of the constants ELk and K_A for cumene reported by Corrigan *et al* (5) differ from those reported in this paper. These differences are due to two causes. First, the cumene feed used by Corrigan and Garver was recovered from previous runs. Slight amounts of impurities would thus accumulate and reduce the reaction velocity constant. Comparison of the ELk vs. $1/T$ plots shows that both lines are parallel, but that of Corrigan *et al* is somewhat lower. This would agree with the previous discussion on the effect of impurities.

Second, a better method of analysis, i.e., infrared spectrophotometry, was available for this latter work. This allowed runs at lower conversion to be made and accurately analyzed, and as

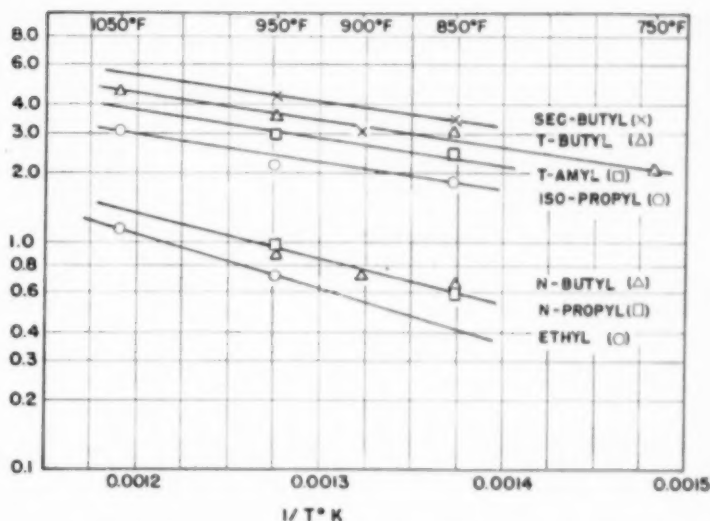


Fig. 10. Reaction velocity constant for coke formation vs. temperature.

the low-conversion data are the most important for evaluation of the constants, it is felt that the values in this paper are more accurate than those previously reported.

Although the differences in the values of K_A and K_B are believed to be within the range of experimental error, it is recommended that the values in this paper be used.

Carbon Formation

Olefins are produced as primary reaction products of the catalytic cracking of alkylbenzenes, and it is generally agreed that olefins undergo hydrogen transfer reactions that saturate some olefins at the expense of others which degenerate to coke. Voge *et al.* (26) have shown that *iso*-olefins are saturated more rapidly than normal olefins and thus also form carbon more rapidly.

Assuming that the carbon formation can be represented as an irreversible first-order reaction, the reaction velocity constant k' for carbon formation was calculated for the various alkylbenzenes from the carbon data obtained in these experiments. Values are presented in Figure 10.

In the alkylbenzene cracking reaction the rate of coke formation, it would seem, depends on the rate of cracking of the alkylbenzene or on the rate of hydrogen transfer in the secondary olefin reaction, whichever is rate controlling. Both of these rates depend on structure of the alkylbenzene. The relative position of the various k' lines in

Figure 10 is in agreement with these concepts except for that of *sec*-butyl, the explanation of which is not now apparent.

Summary

Results of this investigation illustrate that the catalytic cracking characteristics of a family of hydrocarbons, represented by rate equations developed by the methods of Hougen and Watson (13), can be correlated. As increasingly accurate thermodynamic data become available, more reliable correlations should be possible.

Correlations presented permit prediction of reaction velocity constants and adsorption constants for the catalytic cracking of *mono*-alkylbenzenes at all temperatures in the commercial cracking range. These results further suggest that cracking reactions for all hydrocarbons might show similar correlations within each family and that perhaps the enthalpy of activation (ΔH^\ddagger) might be some constant percentage of the heat of reaction (9.62 in this study). This fact alone would save considerable experimentation since it would permit the estimation of reaction velocity constants at all temperatures from only one set of experimental determinations at a single temperature. It should be emphasized that these results are strictly applicable only to the catalyst used in this investigation; however, the results may be extended to other catalysts through the determination of catalyst-activity factors.

A method has been illustrated which enables corrections to be made for impurities in the feed. Correlation of rates of carbon formation with alkylbenzene structure is also suggested.

As more accurate data on bond dissociation energies and ionization potentials of various organic radicals are made available, it will be possible to calculate the relative energies of carbonium ion formation, which may provide a basis for better correlations of catalytic cracking reactions occurring by the carbonium ion mechanism. A small amount of such data has recently become available (22).

Acknowledgment

The authors are grateful to the Standard Oil Company of California and the Wisconsin Alumni Research Foundation for financial assistance, to Socony-Vacuum Corp. for donation of the catalyst, to D. R. Johnson of the University of Wisconsin chemistry department for the infrared analyses, and to Drs. O. A. Hougen, R. B. Bird, and C. F. Curtiss for their kind assistance.

Notation

- E = effectiveness factor
 F = feed rate, g. moles feed/hr.
 ΔG° = free energy change for over-all reaction
 ΔG^\ddagger = free energy change for formation of activated complex from A
 ΔG^\ddagger_{-1} = free energy change for formation of activated complex from R and S
 h' = Planck's constant
 ΔH° = enthalpy change (heat of reaction) for over-all reaction
 ΔH^\ddagger = enthalpy change for formation of activated complex
 ΔH_A = enthalpy change for chemisorption of A
 k = surface reaction velocity constant for catalytic cracking of alkylbenzenes
 \bar{k} = Boltzman's constant
 k' = reaction velocity constant for carbon formation
 K = equilibrium constant for over-all reaction
 K_A = adsorption constant for component A
 K_R = adsorption constant for component R
 L = number of molal active sites per unit mass of catalyst
 L_i = activity factor for impurity correction
 P = probability or steric factor
 p_A = partial pressure of A, atm.
 p_R = partial pressure of R, atm.
 p_S = partial pressure of S, atm.
 R = Gas Law constant, 1.987 cal./g. mole/(° K.)

- r = reaction rate in moles of feed converted/(mass of catalyst)(time)—g. moles(g.)/(hr.)
 r_0 = initial reaction rate
 S = component S
 ΔS° = entropy change for over-all reaction
 ΔS^\ddagger = entropy change for formation of activated complex
 ΔS_A = entropy change for chemisorption of component A
 T = absolute temperature, °K.
 W = weight of catalyst charge in reactor, g.
 x = conversion, moles feed converted/mole of feed fed
 x^* = equilibrium conversion
 Z = collision number

Greek Letters

- α = proportionality constant
 β = constant in integrated equation

$$= \frac{2}{Elk K_A \pi} + \frac{K_R}{Elk K_A}$$
 γ = constant in integrated equation

$$= \frac{1}{Elk K_A \pi} + \frac{1}{Elk}$$
 $\delta = \sqrt{1 + \frac{1}{K}}$
 π = total pressure, atm.

Subscripts

- A = component A = any alkylbenzene
 a = reaction a
 b = reaction b
 R = component R = benzene
 S = component S, = olefin corresponding to component A

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Discussion

R. S. Dicks, (Shell Oil Co., Houston, Tex.): Could either Mr. Rose or Mr. Garver tell me a little about the catalyst properties that were used? Did you measure the surface area, for example?

H. F. Rose: Yes, we have values of the surface area that we checked and also that we received from the catalyst manufacturer. A value of 342 sq.m./g. is representative. If you are interested in the activity of the catalyst—we made a considerable study to be sure that the activity did not vary. In other words, all along we returned to standard runs to check the activity and the activity variation was negligible and at random. One study was made of 60 runs in duration, all at different conditions, and no variation in the activity was found.

Presented at the A.I.Ch.E. Biloxi meeting.

Ion exclusion is a method of separating ionic and nonionic components of a solution by the use of ion-exchange resins. The same chromatographic techniques have also been extended to nonionic separations. This method differs from the usual ion exchange in that no effective chemical reaction takes place. The separation depends upon the differences in the affinity of the exchanger for the solutes. A brief discussion of the theory, application, and operating conditions is presented with primary emphasis on column efficiency. In this study the efficiency of an ion-exclusion column is determined by the elution of a single component (ethylene glycol) from Dowex 50 and analysis of the elution curve to determine the H.E.T.P. It is shown how the H.E.T.P. varies with particle size and cross-linkage of the resin, the flow rate and feed quantity per cycle, and the bed depth.

Ion Exclusion—Column Analysis

D. W. SIMPSON AND R. M. WHEATON

The Dow Chemical Company, Midland, Michigan

The ion-exclusion method described here appears to have its greatest utility in the deionization of aqueous solutions of nonpolar or slightly polar solutes such as alcohols, glycols, weak organic acids, amino acids, ketones, etc. It may be more economical than conventional ion exchange (preferred for low ionic concentrations) or distillation or any of several other possible operations.

Ionic materials are primarily excluded from the resin because of the high ionic concentration within the particles. This may be explained by the Donnan membrane equilibrium if one considers the inside of the resin particles as a true solution surrounded by a semipermeable membrane. In contrast, nonionic materials penetrate the ion-exchange particles to a greater degree. Thus, when passed through a column of ion-exchange resin, the ionic material travels at a faster rate than the nonionic material.

The techniques of ion exclusion have also been extended to the separation of two or more nonionic compounds which have differing degrees of sorption by the resin particles (7), e.g., ethylene glycol and acetone (Fig. 2).

The simplicity of ion-exclusion equipment and controls is reflected in low operating costs. In comparison with deionization by ion exchange, ion exclusion is economical where relatively high concentrations of salts, acids, or alkalis are

involved since the need for chemical regenerants and the time for regeneration are obviated. It is also advantageous for deionizing pH sensitive materials, where the neutral form of ion-exchange resins would be employed. This operation is particularly useful compared to many other processes when highly corrosive and/or heat-sensitive materials are to be separated since the column can be operated at room temperature.

Since ion exclusion is relatively new, it is important to analyze the factors involved. Some important resin properties and column operating conditions were investigated. These factors were studied on the basis of single-component elution curves and a mathematical analysis of these curves was made by previously proposed methods.

Procedure

A column is filled to the desired depth with the proper ion-exchange resin and flooded with a solvent, which is usually water. The feed solution containing two or more separable components is then added with proper distribution to the top of the resin bed. The feed volume and concentration are adjusted so that a separation may be effected for the given operating conditions. In general this feed volume is considerably less than the bulk resin volume. The feed solution is passed down through the column followed by the solvent. As the feed mixture passes through the resin bed, a gradual separation of the solutes

takes place. By the time the solutes are eluted from the column, they may be completely separated.

Two examples of separations made by ion-exclusion methods are included to illustrate the feasibility of the process. Figure 1 shows an essentially complete separation between sodium chloride and ethylene glycol. The highly ionized sodium chloride is virtually excluded from the resin, while the ethylene glycol is distributed more evenly between the two phases, and hence moves at a slower rate down through the column. Figure 2 shows a separation between two non-ionic materials. Since the degree of sorption of acetone by the resin is relatively higher than that of ethylene glycol, the two materials appear in the effluent completely separated. These separations were made using Dowex 50-X8,* 50-100 mesh resin.

Theory

To understand better the theory of ion exclusion, one must first examine the characteristics of the resin bed. Figure 3 represents a magnified section of a column. As illustrated the resin bed

* Dowex 50 is a generic name for a series of strongly acidic styrene base cation exchange resins, containing sulfonic acid groups. The symbol X8 is a measure of the cross-linkage of the resin and is defined by the quantity of divinylbenzene present in the styrene copolymer prior to sulfonation. The cross-linkage may be widely varied for special applications.

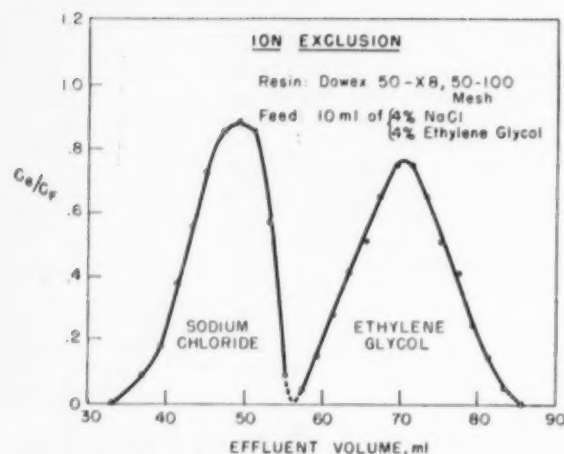


Fig. 1.

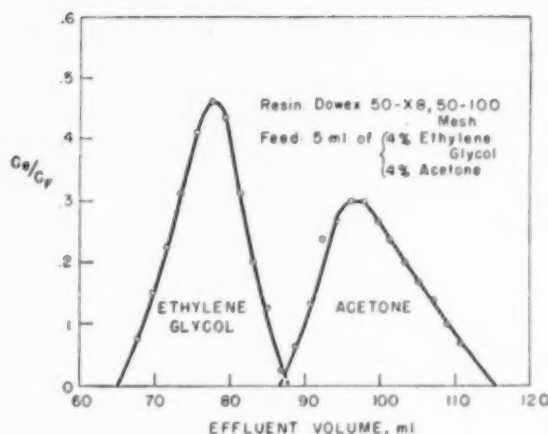


Fig. 2.

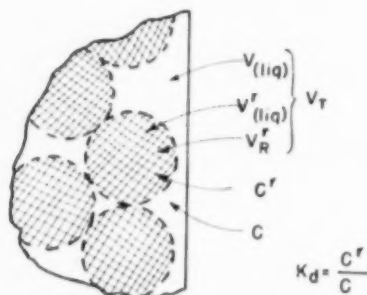


Fig. 3.

consists of three parts: the interstitial volume or the liquid volume between the resin beads, the occluded volume or the volume of liquid held within the beads, and the volume of the resin network or the solid volume. Because of the high ionic concentration within the resin and the organic nature of the resin, the character of the solution inside the resin phase is different from that outside, generally causing an unequal distribution of a solute between the two phases. This distribution coefficient can be defined:

$$K_d = C^r / C \quad (1)$$

where

C^r is the concentration of the solute in the liquid within the resin and

C is the concentration of the solute in the liquid outside of the resin.

This distribution coefficient is different for different solutes and the difference in the K_d values of two or more solutes is a measure of the ease of separation by ion-exclusion methods.

The distribution coefficient determines the rate at which the concentration band of a solute will travel down the column relative to the rate of the carrier liquid. In other words it determines the position of the elution curve of a solute with respect to the effluent volume (see Fig. 4). This can be shown by a material balance. If a feed solution were fed into

a resin bed until a solute first appeared in the effluent, the concentration (C) in the interstitial volume (V_{liq}) would be equal to the initial concentration (C_f) of the solute in the feed. At this point the sum of CV_{liq} and C^rV_r (concentration and volume inside of resin) is equal to the initial feed concentration multiplied by the volume of feed (V_f) admitted to the column. Since the effluent volume is equal to the feed volume and $C = C_f$, the following relation holds:

$$CV_{liq} + C^rV_r = CV_m \quad (2)$$

where V_m = effluent volume to maximum concentration, assuming no forward mixing and complete equilibrium. Even though forward mixing does occur and complete equilibrium is probably not attained, the equation is still a good approximation for the differential curve of a break-through curve. Dividing by C and substituting K_d for C^r/C , Equation (2) can be written as follows:

$$V_{liq} + K_dV_r = V_m \quad (3)$$

Thus, if one knows the distribution coefficient (K_d) of a solute, one can predict its appearance in the effluent. Also, by knowing the K_d values of a mixture of solutes, one may predict the difficulty of their separation by ion exclusion or determine the quantity of feed per cycle.

Column Analysis

An ion-exclusion column was examined for a change in efficiency as some resin property or operating variable was changed. To make such analyses, it is necessary to use experimental data and an applicable method that would measure changes in efficiencies. It has been proposed (3) that a resin bed could be considered analogous to a packed distillation column and that the plate theory could be applied. Using the plate theory concept, Mayer and Tompkins (2) have developed some useful equations from a theoretical plate-by-plate material balance. Using these equations and assuming an elution curve approximates the normal curve of error, L. A. Matheson† suggested the following method for calculating the number of theoretical plates from experimental data:

$$P = \frac{2(C^r + 1)}{(H'')^2} \quad (4)$$

where

P = number of theoretical plates

C^r = $\frac{\text{amount of solute in resin phase}}{\text{amount of solute in liquid phase in equilibrium with resin phase}}$

H'' = half-width of elution curve at an ordinate value of $1/e$ of

† Unpublished.

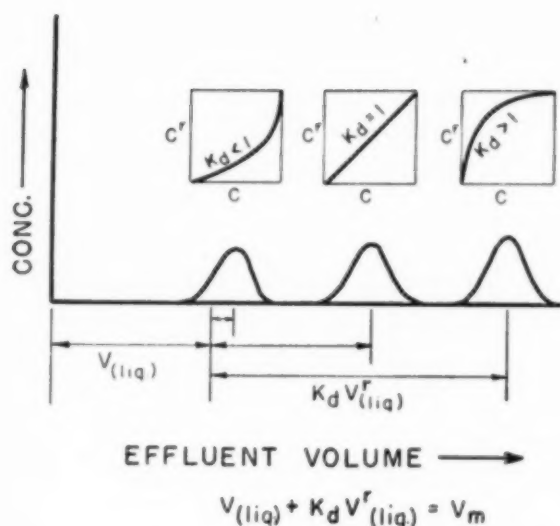


Fig. 4

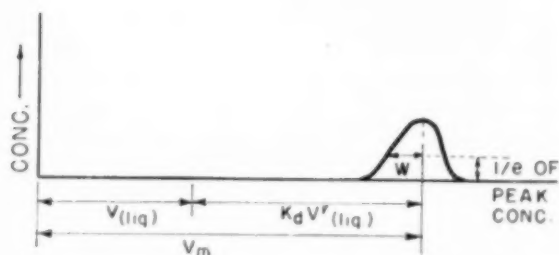


Fig. 5

$$P = \frac{2 V_m [V_m - V_{(liq)}]}{W^2}$$

$$HETP = h/P$$

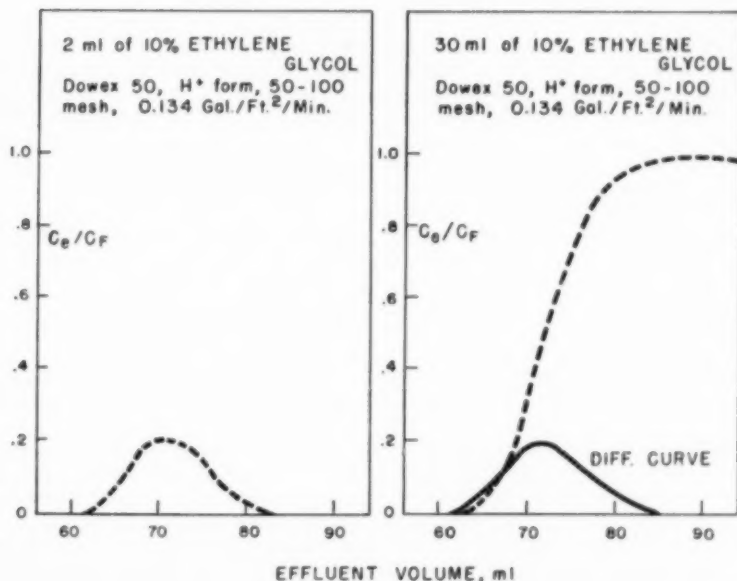


Fig. 6

the peak concentration (where e is the log base)

The C' value may be determined as follows:

$$C' = \frac{C^r I^r}{C I^r_{(liq)}} \quad (5)$$

from Equation (1),

$$C' = K_d \left(\frac{I^r}{I^r_{(liq)}} \right) \quad (6)$$

Solving Equation (3) for K_d and substituting in Equation (6),

$$C' = \left(\frac{I^r_m - I^r_{(liq)}}{I^r_{(liq)}} \right) \left(\frac{I^r}{I^r_{(liq)}} \right) = \left(\frac{I^r_m - I^r_{(liq)}}{I^r_{(liq)}} \right) \quad (7)$$

Substituting Equation (7) into Equation (4) and defining W as equal to $W' I^r_{(liq)}$ then

$$P = \frac{2 I^r_m (I^r_m - I^r_{(liq)})}{W^2} \quad (8)$$

where

W' is measured in the same volume units as I^r , $I^r_{(liq)}$ and I^r_m .

This method, as illustrated in Figure 5, is the method used to determine the number of theoretical plates.

Once the number of theoretical plates has been calculated, the H.E.T.P. can be determined as follows:

$$H.E.T.P. = h/P \quad (9)$$

where

h is the height of the resin bed.

This method of calculating the number of theoretical plates assumes a small feed volume per run. However, it is much better to use the differential curve of a break-through curve of a large feed volume to calculate the number of theoretical plates. This reasoning assumes that a large feed volume is made up of a number of consecutive small feed volumes. Figure 6 shows a comparison between the differential curve obtained from the frontal wave of a large feed volume and that of a small feed volume. This method was used in examining the effect of such variables as the particle diameter and cross-linkage of the resin, the flow rate and quantity of feed per cycle, and the bed height.

Experimental

The experimental data reported here were obtained with resin beds of approximately 100 ml. (column 0.6 in. \times 22 in.). Flow rates were controlled by a stopcock at the bottom of the resin bed while maintaining a constant head pressure. Ethylene glycol feed solutions (10%) were used

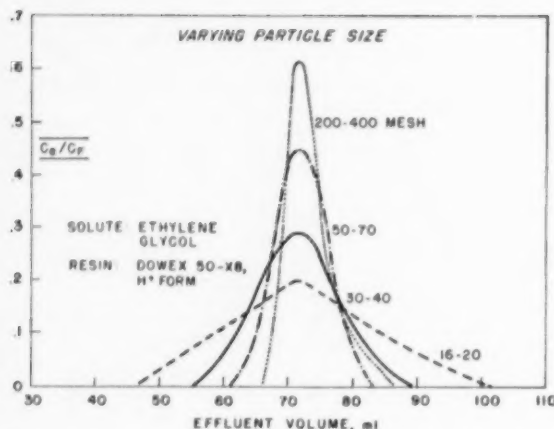


Fig. 7.

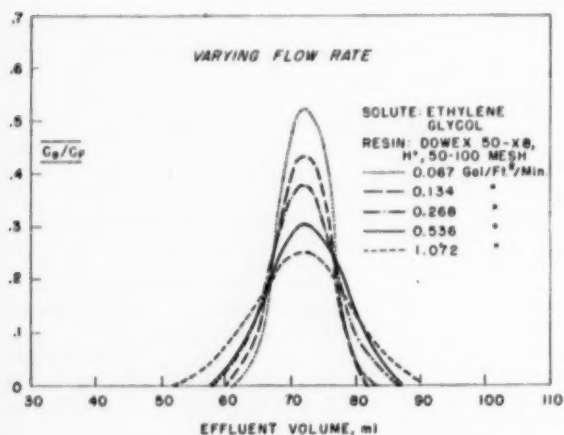


Fig. 9.

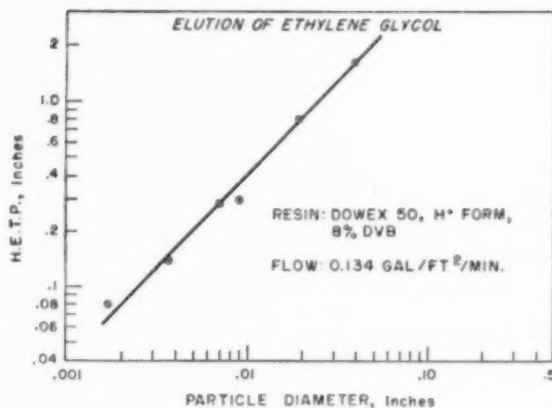


Fig. 8.

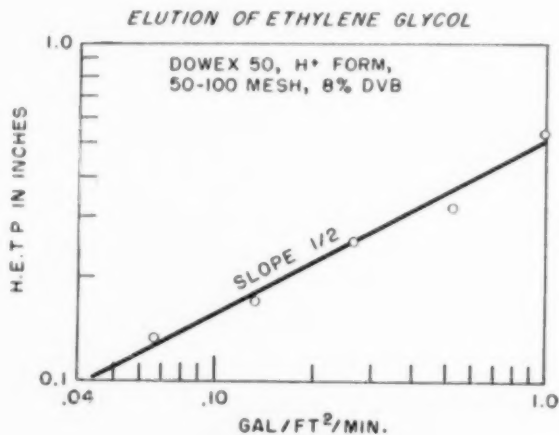


Fig. 10.

in every case because of the symmetry of the elution curves, representing near linear equilibrium in this concentration range. Effluent fractions (generally 2 ml. each) were collected in a series of test tubes by a Technicon Fraction Collector. In plotting the data, the zero point on the abscissa (effluent volume) represents that point at which the feed solution entered the resin bed.

Results

The effect of particle diameter of the resin spheres is shown on Figure 7 for four individual runs, maintaining all other conditions constant. The feed for each run was 5 ml. of 10% ethylene glycol and the flow rate was maintained at 0.134 gal./ft² (min.). This shows that the finer mesh resins gave the sharpest curves. Use of the aforementioned formula to calculate the number of theoretical plates and in turn to determine the H.E.T.P. shows (Fig. 8) that the H.E.T.P. is directly proportional to the resin particle diameter. To obtain the greatest number of theoretical plates, the finer mesh resin should

be used, the practical limit being determined by the pressure drop across the column.

The sharpness of an elution curve improves with reduced flow rates as shown in Figure 9 for the elution of ethylene glycol at five rates. Figure 10 shows that the H.E.T.P. is directly proportional to the square root of the mass velocity of the fluid. As the flow rate increased from 0.067 to 1.072 gal./ft² (min.), the H.E.T.P. increased from 0.132 to 0.535 in. This represents a 16-fold increase in flow rate with a 4-fold increase in the H.E.T.P.

The position of the elution curve with respect to the effluent volume is a function of the cross-linkage of the resin (Fig. 11). This is due to the fact that V^r is an inverse function of the cross-linkage (1, 4). Figure 12 shows that the efficiency of a column decreases somewhat with an increase in cross-linkage, even though the average concentration of the solute in the effluent is somewhat increased. In ion exclusion, the choice of cross-linkage to be used depends on a number of factors:

As the cross-linkage of the resin approaches zero, the resin becomes more gelatinous, which decreases its physical stability and increases the pressure drop across the column. The exclusion factor for ionic materials also diminishes ($K_d \rightarrow 1$). On the other hand, though selectivity is increased, highly cross-linked resins decrease the rate of diffusion within the resin and the ion-exclusion capacity by decreasing the volume of liquid within the resin particles. In practice, a compromise in cross-linkage is generally used, e.g., 4-12% cross-linked Dowex 50 is preferred for most of the separations made by ion exclusion.

Another series of runs was made in which the feed volume was varied, holding all other conditions constant (Fig. 13). It is shown that under identical operating conditions the breakthrough point is the same for the same solute in every run. With other conditions being set, the final average concentration is a function of the initial concentration and the quantity of feed per run. The factor which limits the

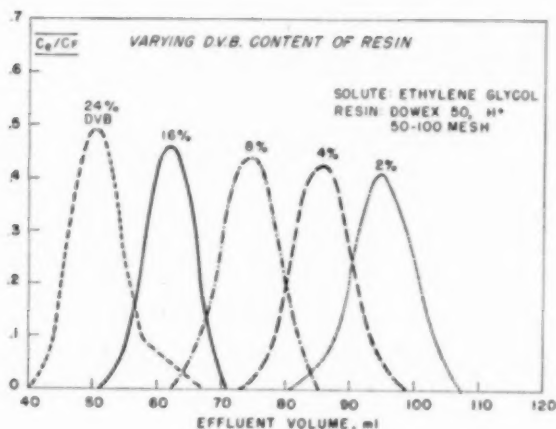


Fig. 11.

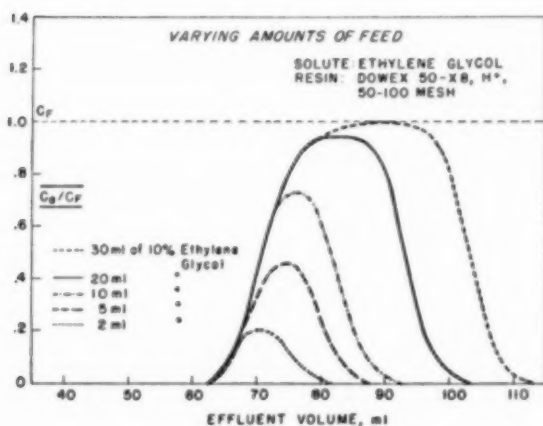


Fig. 13.

quantity of feed that can be used per cycle is the appearance of the second solute in the effluent. The quantity of feed must be adjusted so that a separation may be obtained between the two solutes.

Two runs were made, varying the bed depth, and the H.E.T.P. was found to be invariant with bed depth.

Summary

Though chromatographic separations of the ion-exclusion type are dependent on a number of factors, one of the most important is the difference between the distribution coefficients of the solutes to be separated. The greater the difference in the distribution coefficients, the easier will be the separation by ion exclusion. Another important factor to be considered is the efficiency of the resin bed to be used for the separation. This may be determined by the elution of a single component and analysis of the elution curve to determine the H.E.T.P. It has been found over the range studied that the H.E.T.P. is

directly proportional to the particle diameter and to the square root of the mass velocity of the fluid. It varies slightly with cross-linkage and feed volume and is independent of column height.

Acknowledgment

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Notation

- C' = distribution ratio of a solute in any plate

$$= \frac{\text{amount of solute in resin phase}}{\text{amount of solute in liquid phase in equilibrium with resin phase}}$$

 C = concentration of a solute in liquid phase in any plate
 C' = concentration of a solute in resin phase in any plate
 C_F = concentration of a solute in feed solution
 C_e = concentration of a solute in effluent

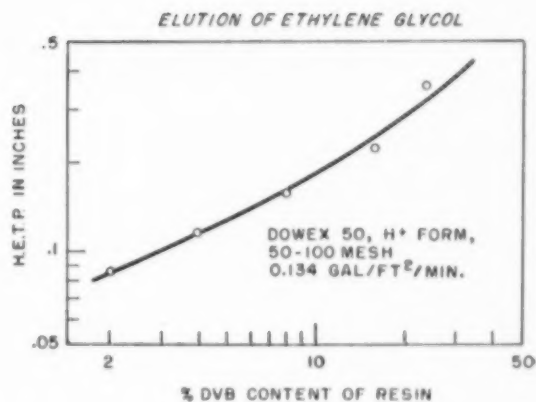


Fig. 12.

- d_p = mean diameter of resin particles, in.
 DVB = divinylbenzene
 h = height of the resin bed, in.
 $H.E.T.P.$ = height equivalent to one theoretical plate, in.
 K_d = distribution coefficient (C'/C)
 P = number of theoretical plates
 V_F = volume of feed solution
 $V_{(1\sigma)}$ = liquid volume in external void space of a resin bed
 $V'_{(1\sigma)}$ = volume of liquid held within resin particles
 V_m = volume of effluent to front of a theoretical square wave
 V_R = volume occupied by resin network or solid volume
 V_T = total volume of a resin bed
 W = half-width of an elution curve at ordinate value of $1/e$ of the peak concentration (where e is the log base). W is measured in the same volume units as:
 $V_{(1\sigma)}$, $V'_{(1\sigma)}$, and V_m
 W' = same as above except that W' is measured in column volumes (liquid volume held between particles in column)

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This is the third successive year that CEP has offered a classification of the year's Ph.D. theses.† The same unit operations, and process descriptions appear as headings, such as Adsorption and Diffusion, and Heat Transfer and Mixing, plus new ones which did not appear in either of the preceding indexes—namely, Aerosols, Conveying, and Particle Size. Again the suggestion is made that in using the index for a subject of interest, more than that specific subject be checked since a title can fall into more than one classification.

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PHOTOCHEMICAL OXIDATION OF SO₂ TO SO₃ AND ITS EFFECT ON FOG FORMATION.* Earl R. Gerhard, University of Illinois. Prof. H. F. Johnstone, 102 pp. Two copies available from university library. Microfilm from University Microfilms, Ann Arbor, Mich., 1¼ cents a page. (September, 1953.)

RATE AND MECHANISM OF THE CATALYZED METHANE-SULFUR VAPOR REACTION. George W. Naber, Purdue University. Prof. J. M. Smith, 162 pp. One copy available in university library. Negative photostats 20 cents a page; positive photostats 40 cents a page; microfilm 7½ cents a frame (equal to one page). (January, 1953.)

STUDY OF HETEROGENEOUS GAS-SOLID CATALYSIS IN A STIRRED FLOW REACTOR. Robert

D. Williams, Columbia University. Prof. C. Potter. Filed in Columbia library. (1953.)

STUDY OF RATE FACTORS IN LIQUID PHASE HYDROGENATION. Herbert G. Krone, Ohio State University. Prof. A. Syverson, 300 pp. One copy available from university library. Limited number abstracts available in August, 1954. (August, 1953.)

Mass Transfer

COCURRENT GAS ABSORPTION—A STUDY OF THE VARIABLES AFFECTING RATE COEFFICIENTS USING A STATISTICAL TREATMENT.* Wayne S. Dodds, Northwestern University. Prof. L. F. Stutzman, 156 pp. Filed with University Microfilms, Ann Arbor, Mich. Microfilm 1¼ cents a page. Abstract available separately. (June, 1953.)

CONDENSATION IN THE PRESENCE OF INERT GASES. William B. Retollick, University of Illinois. Prof. H. F. Johnstone, 115 pp. Two copies available in university library. Microfilm available from University Microfilms, Ann Arbor, Mich., 1¼ cents a page. (July, 1953.)

MASS TRANSFER ON BUBBLE CAP AND PERFORATED PLATES.* Herbert L. Stone, Massachusetts Institute of Technology. Prof. E. R. Gilliland. Filed in Hayden Library of M. I. T. Microfilm and photostats available from library. (February, 1953.)

MECHANISM OF MASS TRANSFER BETWEEN GASES AND LIQUIDS.* Thomas H. Goodgame, Massachusetts Institute of Technology. Prof. T. K. Sherwood. Filed in Hayden Library of M. I. T. Photostats and microfilm available from library. (June, 1953.)

STUDIES OF RATES OF SOLID DISSOLUTION AND OF ELECTRODE REACTIONS AT ROTATING CYLINDRICAL BODIES.* Morris Eisenberg, University of California. Prof. C. W. Tobias and Prof. C. R. Wilke, 134 pp. One copy available in university library. Photostat \$63.09; record print \$28.40. (August, 1953.)

UNSTEADY STATE MASS TRANSFER FROM GAS BUBBLES; LIQUID-PHASE RESISTANCE.* Pong-Sheng Li, University of Washington. Prof. R. W. Moulton, 102 pp. One copy available in university library. Photostats 30 cents a page; microfilm 3 cents a page. (June, 1953.)

Mixing

EVALUATION OF MASS MIXING IN LIQUID EXTRACTION COLUMNS. Peter Kisliak, Rensselaer Polytechnic Institute. Prof. J. O. Hougen, 36 pages. One copy in Rensselaer Library. (June, 1953.)

FUNDAMENTAL STUDY OF THE MIXING OF PARTICULATE SOLIDS. Sherman Weidenbaum, Columbia University. Prof. C. F. Bonilla. Filed in Columbia library. (1953.)

Particle Size

DETERMINATION OF THE SPECIFIC AREA OF PARTICLES BY MEANS OF HINDERED SETTLING. Ernest M. Peres, Jr., Georgia Institute of Technology. Prof. J. M. DallaValle, 84 pp. One copy available from institute library. Photostats 30 cents a page; microfilm 6½ cents a page. (June, 1953.)

DETERMINATION OF SURFACE AREAS OF FINELY DIVIDED MATERIALS BY THE PERMEABILITY METHOD. Robert A. McAllister, Georgia Institute of Technology. Prof. J. M. DallaValle, 91 pp. One copy available in in-

stitute library. Photostats 30 cents a page; microfilm 6½ cents a page. (June, 1953.)

FORCES ACTING IN FLOWING BEDS OF SOLIDS. John Delaplane, University of Delaware. Dr. J. A. Gerster. One copy available in University Memorial Library. (September, 1953.)

Phase Equilibria

CORRELATION AND PREDICTION OF ISOBARIC VAPOR-LIQUID EQUILIBRIUM. Sanford Baranow, University of Cincinnati. Prof. R. H. Price, 45 pp. Two copies available in university library. (August, 1953.)

SALT EFFECT IN VAPOR-LIQUID EQUILIBRIA. Edward T. Fogg, University of Pennsylvania. Prof. A. N. Hixson, 141 pp. One copy available in university library. (June, 1953.)

Thermodynamics

HEATS OF MIXING OF LIQUIDS.* Ching Chang Tsoo, Purdue University. Prof. J. M. Smith, 120 pp. One copy available in university library. Negative photostat 20 cents a page; positive photostat 40 cents a page; microfilming 7½ cents a frame (equals one page). (May, 1953.)

HEATS OF VAPORIZATION OF BINARY LIQUID MIXTURES.* David W. Schroeder, Carnegie Institute of Technology. Dr. W. C. Edmister, 154 pp. Five copies available in inter-library of institute. (March, 1953.)

INTEGRAL ISOBARIC HEATS OF VAPORIZATION OF BINARY SYSTEMS.* John A. Tallmadge, Carnegie Institute of Technology. Dr. L. N. Canjar, 197 pp. Five copies available in inter-library of institute. (July, 1953.)

THERMODYNAMIC PROPERTIES OF ACETONE. Donald A. Moore, University of Michigan. Prof. G. G. Brown, 116 pp. One copy available from general library of university. Positive microfilm 1¼ cents a page. Abstract published in "Microfilm Abstracts." (1953.)

VAPOR-LIQUID EQUILIBRIUM RELATIONS IN THE SYSTEMS: *i*-BUTANOL, METHANOL-*n*-BUTANOL AND ETHYL ETHER-*n*-BUTANOL.* Walter E. Donham, Ohio State University. Prof. W. B. Kay, 97 pp. One copy available in university library. Abstracts available about June, 1954. (June, 1953.)

VOLUMETRIC BEHAVIOR OF NORMAL PENTANE AND PROPANE-PROPYLENE MIXTURES. Kun Li, Carnegie Institute of Technology. Dr. L. N. Canjar, 105 pp. Five copies available in inter-library of institute. (May, 1952.)

Ultrasonics

EFFECT OF ULTRASONIC IRRADIATION ON THE REACTION RATE CONSTANTS IN ACID HYDROLYSIS OF ETHYL ACETATE.* Walter C. Gray, Virginia Polytechnic Institute. Prof. F. C. Vilbrandt, 470 pp. Filed in V. P. I. Library and Microfilm Service. Abstracts available separately, on loan. (June, 1952.)

EFFECT OF ULTRASONICS ON THE KOBE REACTION. Royce E. Siddick, University of Wisconsin. Prof. O. A. Hougen, 110 pp. One copy available in university library. Abstract available separately. (June, 1953.)

EFFECT OF ULTRASONICS AND MICROWAVES ON CHEMICAL REACTION RATE. James C. Bresee, Massachusetts Institute of Tech-

nology. Prof. H. P. Meissner and Prof. H. S. Mickley. Filed in Hayden Library, M. I. T. Photostats and microfilm available from library. (June, 1953.)

Miscellaneous

AIR STERILIZATION BY FIBROUS MEDIA. Arthur E. Humphrey, Columbia University. Prof. E. L. Gaden, Jr. Filed in Columbia Library. (1953.)

BONDING BUTYL RUBBER TO 70-30 BRASS.* Ting Hung Ling, Case Institute of Technology. Prof. G. W. Blum and Prof. E. G. Bohalek, 103 pp. Three copies available from institute library. Abstract available separately. (October, 1953.)

DETERMINATION OF PARTICLE SIZES IN SMOKE.* Roland O. Gumprecht, University of Michigan. Prof. C. M. Stiepecevic, 202 pp. One copy available from general library of university. Positive microfilm 1¼ cents a page. Abstract published in "Microfilm Abstracts." (1953.)

EFFECTS OF HYDROGEN AT HIGH PRESSURES ON THE MECHANICAL PROPERTIES OF METALS.* Hendrick C. Von Nass, Yale University. Prof. B. F. Dodge, 250 pp. Two copies available in Yale Library. (June, 1953.)

FIRE RETARDANT INVESTIGATIONS OF PHOSPHORYLATED AMINOETHYL CELLULOSE STRUCTURES. L. T. Cleary, Columbia University. Prof. J. M. Church. Filed in Columbia Library. (1953.)

INVESTIGATION OF THE POWER REQUIREMENTS FOR MECHANICAL PIGMENT DISPERSION.* John K. Patterson, Purdue University. Prof. R. N. Shreve, 172 pp. One copy available from university library. Negative photostats 20 cents a page; positive photostats 40 cents a page; microfilm 7½ cents a frame (equal to one page). (January, 1953.)

PERFORMANCE OF VANED DISK ATOMIZERS.* William M. Herring, Jr., University of Wisconsin. Prof. W. R. Marshall, Jr. Filed in Wisconsin library. No copies available. (February, 1953.)

RECTIFICATION OF TWO HYDROCARBONS IN THE PRESENCE OF WATER AS A THIRD UNSOLUBLE COMPONENT.* Carl J. Setzer, Ohio State University. Prof. J. H. Koffolt, 95 pp. One copy available in university library. Abstracts available in about a year. (December, 1952.)

STUDY OF THE BONDING AND COHESION ACHIEVED IN THE COMPRESSION OF PARTICULATE MATERIALS. Coy L. Huffine, Columbia University. Filed in Columbia Library. (1953.)

STUDY OF NONCORRODIBLE ELECTRODES.* Donald W. Wood, University of Illinois. Prof. S. Swann, Jr., 128 pp. Two copies available in university library. (January, 1953.)

TENSILE PROPERTIES OF CERTAIN PIGMENTS AND NON-PIGMENTED DETACHED DRYING OIL AND OIL MODIFIED RESIN FILMS.* William J. Snodden, University of Michigan. Prof. L. L. Carrick, 110 pp. One copy available in general library of university. Positive microfilm 1¼ cents a page. Abstract published in "Microfilm Abstracts." (1953.)

TITANIUM-CARBON PHASE DIAGRAM. Irving Codoff, New York University. Prof. J. P. Nielsen, 121 pp. Filed in N. Y. U. Library. (December, 1952.)

ALUMINUM ALLOY REFERENCE SHEET

HARRY W. FRITTS — Aluminum Company of America, New Kensington, Pa.

Wrought Alloys 2S, 3S, and Alclad 3S

Commercial Products:

2S—Sheet, plate, wire, rod, bar, forgings
3S—Sheet, plate, wire, rod, bar, extrusions, tube, pipe, forgings
Alclad 3S—Sheet, plate, tube, pipe

Applications and Remarks:

These alloys, in general, are used for sheet metal work, chemical process equipment, tanks, and similar applications where good resistance to corrosion, weldability, formability, and low cost are required. Alloy 3S has replaced 2S in many applications because of superior mechanical properties. Alclad 3S is a special alloy with a 7½ to 15% surface layer of 72S aluminum metallurgically bonded to a 3S core. Inasmuch as the 72S coating is anodic to the 3S core in most environments, this alloy is particularly useful for chemical equipment, tanks, pipe, and tube, where the commodities being handled have a tendency to induce a pitting type of attack. These

alloys are included in section 8 of the 1952 A.S.M.E. Boiler and Pressure Vessel Code. Alloy 3S is the

most commonly used aluminum alloy for the construction of unfired pressure vessels.

ALUMINUM ALLOY

A.S.T.M. DESIGNATIONS:

2S — 990A
3S — M1A
Alclad 3S — Clad M1A

A.S.T.M. SPECIFICATIONS:

B178, B209, B211, B221, B247, B273
B178, B209, B210, B221, B234, B235,
B241, B247, B273, B274

MECHANICAL PROPERTIES:

	2S	3S and Alclad 3S
Tensile strength, lb./sq.in.	13,000 17,500 24,000	16,000 21,500 29,000
Yield strength, lb./sq.in.	5,000 16,000 22,000	6,000 19,000 26,000
Elongation—% in 2-in. (1/16-in. sheet)	35 9 5	30 8 4
Shear strength, lb./sq.in.	9,500 11,000 13,000	11,000 14,000 16,000
Brinell hardness—500 kg. load, 10 mm. ball	23 32 44	48 40 55

PHYSICAL PROPERTIES:

	2S	3S and Alclad 3S
Modulus of elasticity, lb./sq.in.	10,000,000	10,000,000
Specific gravity	2.71	2.73
Weight—lb./cu.in.	0.098	0.099
Melting range, °F.	1190°-1215°	1190°-1210°
Thermal conductivity—B.t.u./ (hr.) (sq.ft.) (°F./in.)	1539 (—0)	1335 (—0)
Average coefficient of thermal expansion—in./F. x 10 ⁻⁶	1510 (—H18)	1074 (—H18)
—76° — 468°	12.1	11.9
—68° — 212°	13.1	12.9
—68° — 392°	13.7	13.4
—68° — 572°	14.2	13.9
Electrical Conductivity—% of International Annealed Copper Standard	59 (—0)	50 (—0)
	57 (—H10)	40 (—H18)

Composition:

2S — 99.0% Al minimum
3S — 1.2% Mn, balance Al
Alclad 3S — 72S cladding is 1% Zn, balance Al, core same as 3S

Formability: These alloys are relatively soft, ductile and easily formed, especially in the softer tempers. They can be machined using high machine speeds and high rake angle. Cuttings will be stringy and weak.

Heat-Treatment: Alloys 2S, 3S, and Alclad 3S are all nonheat-treatable wrought alloys. Their strengths are increased by cold working.

Weldability: These alloys can be welded by all the common methods. Inert gas shielded arc welding is preferred where flux removal presents a problem, such as in piping, small tanks, or complicated equipment. All three alloys are normally welded with 2S wire, especially where maximum resistance to corrosion and elongation are desirable in the weld zones. No special techniques are necessary for welding Alclad 3S. The 72S cladding electrochemically protects the weld and cut areas.

CORROSION RESISTANCE

ACIDS

Acetic, all concs., r.t.*	E
Acetic, other than glacial, boiling	E
Acetic Glacial, boiling*	E
Acetic Anhydride, r.t.*	E
Acrylic, Glacial, r.t.*	E
Benzic, sat. soln., boiling*	E
Boric, 7% soln., 180° F.*	E
Butyric, all concs., r.t.*	E
Butyric Anhydride, r.t.*	E
Carbolic (phenol), all concs., to 240° F.*	E
Carbonic, all concs., r.t.*	E
Chronic, below 10%, r.t.	E
Creylic (Cresol), r.t.	E
Fatty, up to boiling	E
Hydrochloric, all concs.	E
Hydrocyanic, all concs., r.t.*	E
Hydrofluoric, anhydrous, 200° F.	E
Hydrofluoric solutions	E
Lactic, anhydrous, r.t.*	E
Lactic, up to 10%, r.t.*	E
Maleic, 30%, r.t.	E
Maleic, Anhydride, molten*	E
Malic, to 50%, r.t.	E
Naphthenic, up to 180° F.*	E
Nitric, above 82%, to 120° F.*	E
Nitric, below 82%, r.t.	E
Nitric, Red Fuming, up to 120° F.*	E
Oleic, up to boiling*	E
Oxalic, all concs., r.t.*	E
Oxalic, all concs., elevated temperature	E
Phosphoric, all concs.	E
Phthalic, molten	E
Phthalic Anhydride, molten*	E
Propionic, all concs., r.t.*	E
Propionic Anhydride, r.t.*	E
Stearic, up to boiling*	E
Sulfuric, fuming	E
Sulfuric, other than fuming	E
Sulfurous, r.t.	E
Tannic, all concs., pure, r.t.	E
Tartaric, all concs., r.t.*	E

ALKALIES

Ammonium Hydroxide, comm'l., r.t.*	E
Calcium Hydroxide, all concs.	N
Potassium Hydroxide, all concs.	N
Sodium Hydroxide, all concs.	N

ALKALINE SALTS

Potassium Carbonate, all concs.	E
Sodium Bicarbonate, r.t.*	P
Sodium Carbonate, all concs.	P
Sodium Sulphide	P

NEUTRAL SALTS

Calcium Chloride, all concs., to 200° F.*	G ²
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RATINGS:

E—Excellent resistance, 0.001 max. (in.) year of penetration. Corrosion as slight as to be harmless.

Calcium Sulfate, sat. soln., r.t.*	G ²
Calcium Sulfide, all concs., r.t.*	G
Magnesium Chloride, all concs., r.t.	G ²
Magnesium Sulfate, to 50% soln., r.t.	G
Potassium Chloride, all concs., r.t.	G ²
Potassium Nitrate, all concs., r.t.	E
Potassium Sulfate, all concs., r.t.	E
Sodium Chloride, all concs., r.t.*	G ²
Sodium Nitrate, all concs., r.t.*	E
Sodium Sulfate, all concs., r.t.*	E

ACID SALTS

Alum. paper makers, r.t.*	E
Aluminum Chloride, dry, 70° F.	G
Aluminum Chloride, moist	P
Aluminum Sulfate, r.t.*	E
Ammonium Chloride, all concs., r.t.*	G ²
Ammonium Nitrate, all concs., to 285° F.*	E
Ammonium Sulfate, all concs., r.t.*	E
Copper Chloride, Nitrate, Sulfate	P
Ferric Chloride, Nitrate, Sulfate	P
Lead Chloride, Nitrate, Sulfate	P
Mercury Salts	N
Nickel Chloride, Nitrate, Sulfate	P
Silver Salts	P
Stannous and Stannic Salts	P
Zinc Chloride	P

GASES

Acetylene, dry*	E
Air, wet or dry, hot or cold*	E
Ammonia, dry*	E
Bromine	N
Carbon Dioxide, wet or dry, hot or cold*	E
Chlorine, wet or elevated temps.	N
Freons*	E
Hydrogen Sulfide, wet or dry, hot or cold*	E
Nitrogen, wet or dry, hot or cold*	E
Oxygen, wet or dry, hot or cold*	E
Sulfur Dioxide, dry	E
Sulfur Dioxide, wet	E

ORGANIC MATERIALS

Acetone, r.t.*	E
Alcohols, methyl, ethyl, etc., pure, r.t.*	E
Aniline, all concs., to 212° F.	G
Benzaldehyde, r.t.*	E
Benzene, to boiling*	E
Carbon Disulfide to boiling*	E
Carbon Tetrachloride, dry, r.t.*	E
Chloroform, dry, r.t.	E
Ethyl Acetate, pure, r.t.	E
Formaldehyde*	G ²
Furfural, r.t.*	E
Gasoline, to boiling*	E

G—Good resistance, 0.001-0.012 in./year of penetration. Satisfactory service expected; at most a slight etch.
F—Fair resistance, 0.012-0.120 in. of penetration/year. Satisfactory service under specific conditions. Light to moderate attack.

P—Poor resistance, 0.120-0.520 in. of penetration/year. Satisfactory for temporary service only.
N—Aluminum not recommended. Rate of attack high.
r.t.—Room temperature.

Glycerine, to boiling*	E
Glycols, ethylene and propylene, r.t.*	E
Mercaptans, Amyl, r.t.*	E
Methyl Ethyl Ketone*	E
Oils, crude, essential, refined, vegetable*	E
Oils, sour crude (H ₂ S)*	E
Trichloroethylene, dry, r.t.*	E

PICKLING OPERATIONS

Acetic Acid (Mag. Products)*	E
Sulfuric plus dichromate	N
Sulfuric plus hydrochloric	N

FOOD INDUSTRY

Brines, inhibited*	E
Edible Oils and Fats*	E
Fatty Acids*	E
Fruits and Fruit Juices*	E
Vegetables*	E
Milk Products*	E
Beer	E

PAPER MILL APPLICATIONS

Kraft Liquor	N
Black Liquor	N
Green Liquor	N
White Liquor	F
Sulfite Liquor	P
Chloride Bleach Solution	P
Chloride Bleach Vapors	G
Hydrogen Peroxide (above 30%)*	E
Paper Makers Alum*	E
Humid and Chemical Atmospheres*	E

PHOTOGRAPHIC INDUSTRY

Humid Atmospheres*	E
Cellulose Acetate*	E
Acetic Anhydride*	E
Developers	P
Silver Nitrate	P
Solutions containing SO ₂	P

FERTILIZER INDUSTRY

Ammonia, anhydrous*	E
Ammoniated Ammonium Nitrate*	E
Urea*	E

* Aluminum alloys used commercially.

+ Subject to pitting-type corrosion.

1 Must have trace of moisture present at boiling temperature.

2 May be inhibited with sodium chromate.

No. 29

Plans for the Future Dominate St. Louis Meeting

The future of the A.I.Ch.E. and discussion of several positive plans emerged as the dominant theme of the St. Louis meeting, held in December. St. Louis by registering 1,948 topped Cleveland from the No. 2 spot in attendance totals at meetings. The well-attended St. Louis conference was supercharged with optimism as new plans, reports, and the introduction of several meeting formalities were revealed.

The first step for the future was taken by Council when it declared that the A.I.Ch.E. would cooperate wholeheartedly with other major engineering societies in organizing a National Engineering Center. A.I.Ch.E. efforts to obtain a separate building will be channeled for the present into a joint effort with the other engineering societies. Then the Publication Committee presented its long-awaited report on the publication needs of the Institute, and

this, along with the report of the Future of the Institute Committee, resulted in action by Council to appropriate some of the Institute resources to a new publication recommended by the Publication Committee.

A panel session on Sunday afternoon revealed tentative plans to abandon the present titles of membership in favor of a standard form recommended by the Engineers' Joint Council, a goal toward which all engineering societies are working. Council, it was also announced, is planning soon to introduce to the members suitable modifications of the constitution which will enable Junior members to vote for Institute officers.

Another historic event took place when President Nichols announced the formation of a new Nuclear Engineering Division. This first division within the A.I.Ch.E. is an outgrowth of the work of the Committee on Nuclear Energy. The new division will have A.I.Ch.E. members as officers, but provision is made on its governing board and in its membership structure for those who do not belong to the A.I.Ch.E. The new division will function with autonomous responsibility similar to that of local sections. At St. Louis the officers of the division held an organizational meeting, accepted a constitution under which it will operate, and elected Professor Donald L. Katz of the University of Michigan as chairman.

At the banquet on Tuesday evening two innovations occurred. The "great gavel of the A.I.Ch.E." was passed to Chalmers Kirkbride as incoming president. This was the first of what is hoped to be a long series of traditional gavel presentations at the annual Awards Banquet of the A.I.Ch.E. Second was the presentation to President Nichols of a special pin symbolizing his term of office as president.

The following awards were made at the banquet: Professor W. R. Marshall, Jr., the William H. Walker Award; Professor Le Roy A. Bromley, the Junior Member Award; and George E. Holbrook, the Professional Progress Award. In the contest for the A. McLaren White Award, Raymond M. Cartier won first prize; Donald W. Sundstrom, second prize; and Shmuel Danker, third prize. Honorable mention in this contest went to Robert L. Kendig, Vladimir L. Stokov, and Robert W. Scher. Biographies of these award winners appeared in the November and December issues of Chemical Engineering Progress.



George E. Holbrook, left, assistant director, development department, E. I. duPont de Nemours & Co., received the Professional Progress Award. J. H. Worth of Celanese Corp. presented the check for \$1,000.



The William H. Walker Award for 1953 was made to W. R. Marshall, Jr., left, associate dean of the college of engineering and professor of chemical engineering at the University of Wisconsin.



C. G. Kirkbride, new President of A.I.Ch.E., left, receives gavel from retiring President W. T. Nichols.



▲ LeRoy A. Bromley, left, associate professor of chemical engineering at the University of California, Berkeley, won the Junior Membership Award. Prof. O. A. Hougen, right, was 1953 Awards Committee Chairman.

John C. Paul, Jefferson Chem. Co.; Karl Kammeyer, Iowa State Univ.; Irwin R. Higgins, Oak Ridge National Lab. and C. R. Wilkie, Univ. of California, presented technical papers.



▲ The A. McLaren White Award for the best solution to the student contest problem went to Raymond M. Cartier, graduate student at Brooklyn Polytechnic Institute. Carl Monrad, center, was chairman of student chapters committee for 1953, and W. T. Nichols, Monsanto Chemical Co., made the presentation.

L. E. Colburn, J. F. Pritchard & Co.; W. D. Luenig, Sinclair Refining Co.; A. B. Wilder and K. E. Strain, Du Pont Co.





period heretofore necessary with the kettle process. The same company also produces synthetic detergents on a continuous basis."

K. S. Watson, C. E. Renn, Johns Hopkins Univ.; F. R. Weston, Atlantic Refining Co.; John Oliver, Du Pont Co.; and George F. Jenkins, Carbide and Carbon Chemicals Co.

◀ Paul E. Heisler, Monsanto Chemical Co.; Mrs. Heisler; Mrs. Dwight Miller; and Mr. Miller of Sharples Chemical Co., Trenton, Mich.



Group from the A.I.Ch.E. Student Chapter of Washington Univ., in attendance at the Sunday evening get-together.



Mrs. Stanley Lapota, chairman of Ladies Committee.



Plant trips desk. James Riggs, Minn. Mining & Mfg. Co.; Robert Yates, plant trips committee man, of Monsanto Chemical Co.

"he must also himself refrain from creating it."

M. F. Gautreaux, coauthor of "Effect of Length of Liquid Path on Plate Efficiency," deemed by the committee headed by Dr. Clyde McKinley to be the person who had presented his paper in the best manner, was named award winner.

Ewan Clague, Commissioner of Labor Statistics, Department of Labor, Washington, D. C., opened the technical session with a paper, "Yardsticks of Productivity and the Use of the Productivity Concept in Industry."

In his speech "Process Industries of St. Louis," Dr. Lawrence E. Stout, Sr., dean of the School of Engineering, Washington University, covered the new technical developments in the brewery industry and the soap and detergent field, as well as engineering developments in the petroleum industry of the St. Louis area. In one portion of his paper Dean Stout asserted that the introduction of continuous operations had displaced batch operations as traditional soap-making process. In the St. Louis factory of Procter & Gamble, "the continuous countercurrent hydrolysis and continuous distillation and neutralization of fatty acids," he reported, "make it possible to obtain finished soap within a few hours after the fat is received by the factory instead of the fifteen-day

Session on Drying included, seated: T. R. Mitchell, Olin Industries; Professor Edgar L. Piret, University of Minnesota; W. B. Van Arsdel, U. S. Dept. of Agriculture; J. D. Seader, University of Wisconsin. Standing: E. D. Besser, U. S. Naval Ordnance Test Station; Walter C. Soeman, Olin Industries; William Herring, Standard Oil Co.; Lawrence Stout, Jr., Colgate-Palmolive Co.; and Lawrence Stout, Sr., who presided.



▲ Standing: A. P. Ting, Catalytic Construction Co.; R. L. Huntington, University of Oklahoma; Warren E. Hesler, Swenson Evaporator Co. Seated: Fred Tuttle, Dow Chemical Co.; Jagdish C. Agarwal, Blaw-Knox Co.; and Thomas F. Reed, U. S. Steel Corp.



▲ Another group at the get-together: K. R. Hancock, chairman, Hotel & Meeting Rooms Committee; C. W. Swartout, general chairman, St. Louis Annual Meeting; Mrs. A. B. Hancock, A. T. Pickens, C. K. Williams Co.; Mrs. A. T. Pickens, and Ralph Cook, Olin Industries.

Heat-Transfer session included, seated: H. J. Ramey and J. B. Henderson, Purdue Univ.; V. W. Uhl, Lehigh Univ.; R. L. Pigford, University of Delaware; and W. W. Wamsley, University of Washington. Standing: Clyde Orr, Jr., Georgia Institute of Technology; L. N. Johanson, University of Washington; Stuart Churchill, University of Michigan; Allen S. Foust, of Lehigh Univ.; and James G. Knudsen, Oregon State College ▶



HORN OF AMALTHAEA

Early in December some fifteen hundred political, social, and physical scientists, including economists, politicians, professional crapehangers, industrialists, and internationalists, met in Washington, D. C., as guests of the Ford Foundation's Resources of the Future, Inc., to explore potential resources. The objective, in terms of the program, was "to survey the natural resources of the nation, explore the demands that may be placed upon them during the next twenty-five years, and investigate methods of use and conservation."

The conference was divided into eight sections, covering land and land resources, the water resource problem, nonfuel minerals, energy resources, U. S. concern with world resources, problems in resources research, and patterns of cooperation.

Three Basic Questions

The basic questions which the conferees tried to explore were three. First, will the resource base of the nation be so diminished during the next twenty-five years as to precipitate a series of critical situations? Second, can such situations satisfactorily be left to extemporaneous solution, or have we reached a point in our economic development when it is desirable for industry, government, and citizens to work toward co-ordinated resource study and action? Third, do we know enough about resources—their interrelationships, possibilities for substitution, technological advances, and the needs and resources of other nations—to foresee and mitigate critical situations?

The conference split early into the Malthusians and the Cornucopians. The Malthusians, unhappy about the rate of resource use, demanded stringent conservation. The Cornucopians, a concept introduced by Earl Stevenson, president of Arthur D. Little, Inc., one of the keynoters at the opening session and chairman of Section 7 on Problems in Resources Research, believed in the continuing ability of man to provide more and more of the basic necessities and conveniences of life from world resources.

There were few corners of human activity that the conference did not explore. Each section held panel sessions keynoted by a steering committee exploring parts of the individual problem. According to plan, the conference itself reached no conclusions, but out of the welter of discussion, opinions, and com-

ment came a series of thoughtful papers and reports which will serve as basic reading for resource managers of the future. All of them showed, though, the inherent difficulty in solving for some future generation problems that are yet unrecognized and unstated.

One of the important sessions on patterns of cooperation under the chairmanship of H. Christian Sonne, chairman of the board of Amsinck Sonne & Co., New York, undertook the task of blueprinting methods of cooperation between citizens' organizations and scientific groups and concluded that resource management should not be left to the inevitable increase of scientific knowledge and technology. "We must maintain an active interest in resource management through government and private bodies," they said, "if we are to meet problems in time to avert a calamity. Our political traditions prevent complete centralization of the problem but must contribute to the effort, and while it is easy to get cooperation on specific programs, mankind ought, in general, to work out better integrated programs to meet the complex resource situations of the future."

The behavioral sciences and communication techniques were nominated to carry knowledge of the best resource practices to the people, and in a final recommendation "continuing study and investigation of patterns of cooperation" were urged upon the conference.

But while Group 8 was blandly assuming that there would be an "inevitable increase of scientific knowledge and technology," Group 7, which concerned itself mostly with science, research, and the help that research can give to resource utilization, was wondering whether man had not made a mistake in developing his civilization beyond his amoebic beginnings when he had consumed only renewable resources. At one stage in the discussion doubt was thrown upon the wisdom of research since "research increases consumption and this is not good." However, the Cornucopian philosophy prevailed.

One of the major problems which the section deliberated at length, was the need for trained men to carry on the research of the future. Much time was given to exploration of deficiencies in the educational system, and fear was expressed that it may even now be too late to give adequate training to the researchers who must provide the answers a quarter of a century hence. Concerning education and educators, the final report said, "Analysis has shown that those en-

tering the field of education have relatively low intelligence quotients; it is common knowledge that the public accords them not merely low esteem and inferior status, but inadequate economic support, hence seems to be getting what it pays for."

It was further pointed out that the need for resources research "is predicated upon a growing population with expanding requirements and transcends the normal processes of growth and undergoes dynamic change. The conclusions of the research section said that examination of the manifold problems presented by population, ranging from reproduction and statistics to social patterns, may prove an essential prerequisite for an intelligent approach to the balance of the resources problems. "Perhaps society is not yet ready for such an investigation with all of its ramifications," but, states the report, "neither are scientists prepared to undertake to carry it through to its logical conclusions. For this reason it is likely to be a continuing element in the entire program of research, and one to which profounder intelligence can be brought as basic discoveries are made in fundamental sciences."

The report also stressed the severe limitations that are placed upon science and technology by shortages of personnel and urged continued efforts to draw upon the reserve of intelligent people who do not now enter college. It called for a reexamination of the areas of popular research which are overfinanced and overmanned to give a better perspective and encouragement to those researchers who have the temperament to enter more venturesome fields.

Throughout the research discussion, however, the need for communication between disciplines was apparent. Problems discussed by the scientists of one field had a solution or the beginning of one in other fields.

Water Resources

The conferees on water resources problems concentrated their work in three areas of study—supply, use, and competitive demands of water; the division of responsibilities for water resources among private groups and local, state, and federal governments; and the principles of evaluation and reimbursement of water resources projects. They accepted as basic the fact that water is a most abundant vital national resource

(Continued on page 56A)

INTALOX SADDLE PACKING DISTILLS 10% MORE CHARGE IN 10% LESS TIME

Field experience is consistently bearing out earlier test data reflecting the greater efficiency of Intalox Saddle Packing. But it is infrequent to have such excellent comparative data as that furnished us by a major manufacturer of organic chemicals.

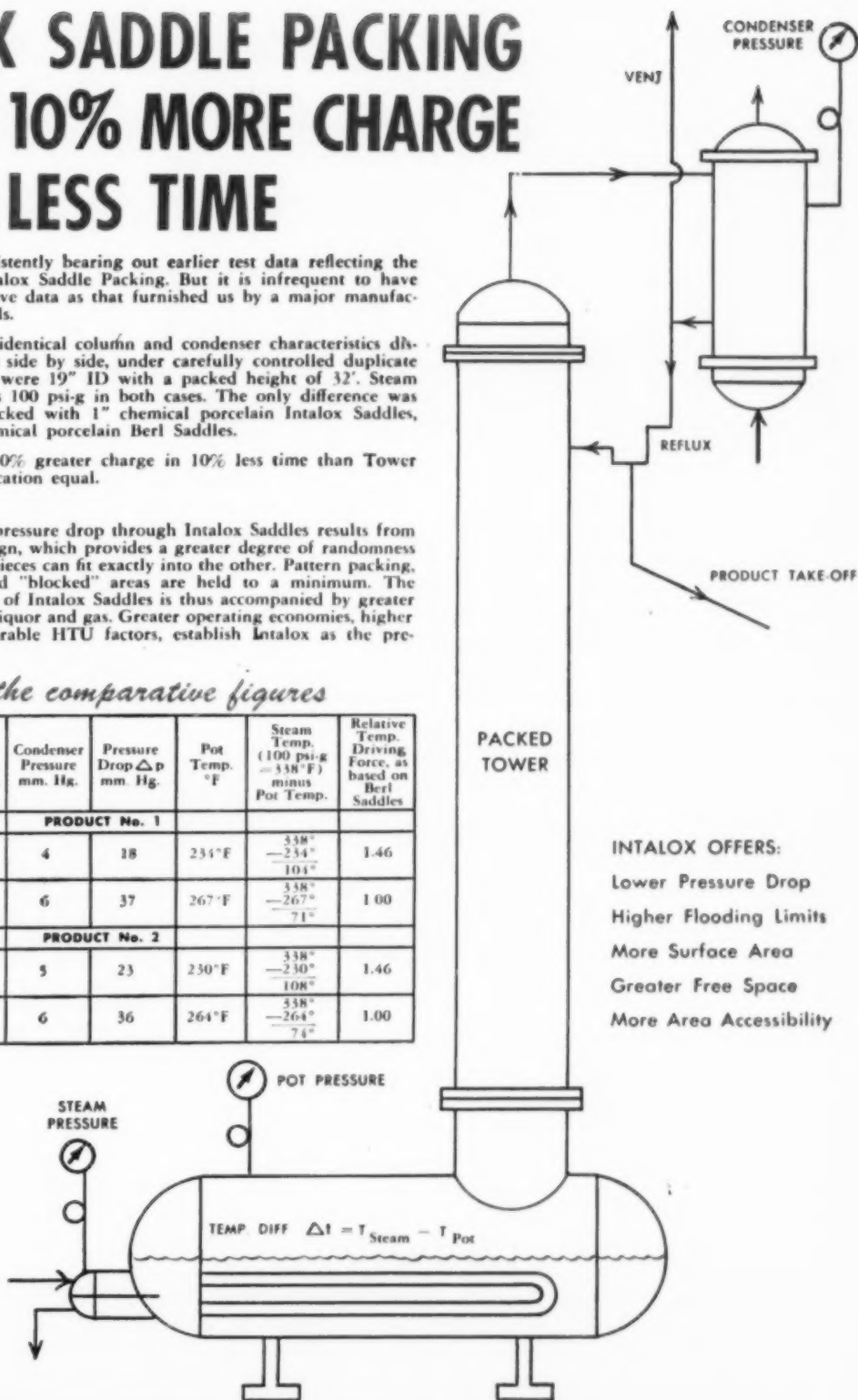
Two column stills with identical column and condenser characteristics distilled the same materials side by side, under carefully controlled duplicate conditions. The Towers were 19" ID with a packed height of 32'. Steam pressure in the coils was 100 psi-g in both cases. The only difference was that Tower "A" was packed with 1" chemical porcelain Intalox Saddles, Tower "B" with 1" chemical porcelain Berl Saddles.

Tower "A" handled a 10% greater charge in 10% less time than Tower "B" with product specification equal.

The substantially lower pressure drop through Intalox Saddles results from the unique, patented design, which provides a greater degree of randomness in packed beds. No two pieces can fit exactly into the other. Pattern packing, nesting, over-lapping and "blocked" areas are held to a minimum. The greater total surface area of Intalox Saddles is thus accompanied by greater available surface area to liquor and gas. Greater operating economies, higher product yields, and favorable HTU factors, establish Intalox as the preferred packing.

Here are the comparative figures

Tower	Type of Packing	Pot Pressure mm. Hg.	Condenser Pressure mm. Hg.	Pressure Drop Δp mm. Hg.	Pot Temp. °F	Steam Temp. (100 psi-g = 338°F) minus Pot Temp.	Relative Temp. Driving Force, as based on Berl Saddles
PRODUCT No. 1							
A	1" Intalox Saddles	22	4	18	234°F	$\frac{338^\circ}{-234^\circ}$ 104°	1.46
B	1" Berl Saddles	43	6	37	267°F	$\frac{338^\circ}{-267^\circ}$ 71°	1.00
PRODUCT No. 2							
A	1" Intalox Saddles	28	5	23	230°F	$\frac{338^\circ}{-230^\circ}$ 108°	1.46
B	1" Berl Saddles	42	6	36	264°F	$\frac{338^\circ}{-264^\circ}$ 74°	1.00



INTALOX OFFERS:

- Lower Pressure Drop
- Higher Flooding Limits
- More Surface Area
- Greater Free Space
- More Area Accessibility

166-4

U. S. STONEWARE
AKRON 9, OHIO



Hard at work on plans for the first world congress on atomic energy are the A.I.Ch.E. members pictured above with representatives of the Atomic Energy Commission. From left to right are J. G. Beckerley, director, declassification section, Atomic Energy Commission; Leon Chrzan, assistant supervisor, chemical engineering section, Ethyl Corporation Research Laboratories; Alberto Thompson, director of information services, Atomic Energy Commission; Stephen Lawraski, director of chemical engineering division, Argonne National Laboratories; J. A. Lane, associate chief of process design section, technical division, Oak Ridge National Laboratories; L. E. Brownell, assistant professor, department of chemical and metallurgical engineering, University of Michigan; R. R. White, professor, dept. chem. & met. eng., University of Michigan; F. J. Van Antwerpen, editor of CEP; D. L. Katz, chairman, dept. chem. & met. eng., University of Michigan; J. J. Martin, associate professor, dept. chem. & met. eng., University of Michigan; H. J. Gomberg, assistant director of Phoenix project, University of Michigan; L. C. Widdoes, project engineer, Michigan Memorial-Phoenix project; Stuart McLain, senior chemical engineer, Argonne National Laboratories; T. B. Drew, professor of chemical engineering, Columbia University; S. L. Tyler, executive secretary, A.I.Ch.E.; G. G. Brown, dean of the college of engineering, University of Michigan; and J. W. Clegg, supervisor of chemical research, Battelle Memorial Institute.

A.I.C.H.E. SPONSORS NUCLEAR CONFERENCE

That A.I.Ch.E. members' thinking is in line with current world developments is proved by their formal announcement of a world conference on nuclear energy only two days after President Eisenhower's proposal for international atomic energy conferences for peace. The five-day meeting at the University of Michigan, sponsored by the university and A.I.Ch.E., will be held from June 20 to 25, 1954. The sponsors have invited the participation of European and Asiatic nuclear scientists, and representatives from Belgium, Canada, France, Great Britain, India, Italy, The Netherlands, Norway, Spain, and Sweden have accepted so far. In the United States the Institute has secured the cooperation of government, industrial and educational organizations.

Don Katz, chairman of the program committee, has announced that for the first time information heretofore restricted has been declassified by the A.E.C., for presentation at the meeting, and he adds that he understands the British atomic authority is following the same procedure.

Members of A.I.Ch.E. will be interested in such conference topics as the application of radioactive products, nuclear reactor types and operation, processing of irradiated materials, education for nuclear engineering; and for the general public there will be less technical talks by national and international experts, such as W. Sterling Cole, chairman of the Joint Committee on Atomic Energy.

OIL PRODUCTION HITS RECORD, SAYS A.P.I.

For the first time the oil industry in the United States will have an operable refining capacity in excess of 8 million barrels a day, according to a survey recently completed by the American Petroleum Institute. By December 31, 1953, capacity was expected to reach 8,079,000 barrels a day, an increase of 494,000 barrels over the figure reported for the same date in 1952.

T.V.A. BEGINS NUCLEAR POWER STUDY FOR A.E.C.

The same type of study as that pursued by private industrial groups working with the Atomic Energy Commission has been approved for the Tennessee Valley Authority. T.V.A. will try to reach conclusions on the immediate and long-range possibilities of commercial nuclear power. T.V.A. at present supplies a major portion of power for A.E.C. facilities at Oak Ridge, Tenn.,

and Paducah, Ky. All costs of the one-year study will be borne by T.V.A., which will submit reports and recommendations to the A.E.C. Title to inventions and discoveries and disposition of reports made in the course of the study will be determined by the Commission.

N.S.F. NAMES COMMITTEE TO STUDY FEDERAL AID

Establishment of a National Science Foundation Advisory Committee to consider the effects of government support to colleges and universities on their research and teaching functions was announced today by Alan T. Waterman, director, National Science Foundation. Members of the committee are Arthur S. Adams, president, American Council on Education; Vannevar Bush, president, Carnegie Institution of Washington; James S. Coles, president, Bowdoin College; Harold W. Dodds, president, Princeton University; Conrad A. Elvehjem, dean of graduate school, University of Wisconsin; T. Keith Glennan, president, Case Institute of Technology; Virgil M. Hancher, president, State University of Iowa; William V. Houston, president, Rice Institute; Clark Kerr, chancellor, University of California, Berkeley; C. N. H. Long, professor of physiology, Yale University; Don Price, associate director, Ford Foundation; Julius A. Stratton, provost, Massachusetts Institute of Technology.

NEW ENGINEERS IN DEMAND AT MORE MONEY

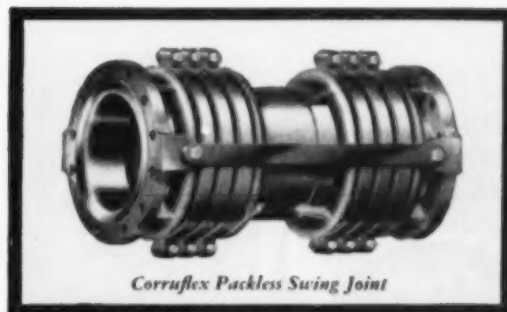
Demand for beginning technical employees in 1954 is fixed at the 1953 level, according to about half of the companies queried by the Midwest College Placement Association. Fifty-two per cent of the 143 companies polled said that they wanted the same number that they had hired in 1953; the rest were about evenly divided between more and fewer. The same question asked a year ago found 56% wanting the same number as in the previous year, 33% wanting more, and 10% wanting fewer.

Despite this leveling of demand, salary scales are continuing to rise, the same group indicated. A starting salary of between \$351 and \$375 was named by 44% of the companies; 36% will offer between \$326 and \$350; and 8%, between \$301 and \$325. A year ago 42% were offering a figure between \$301 and \$325; 43%, between \$326 and \$350; and 6%, between \$351 and \$375.

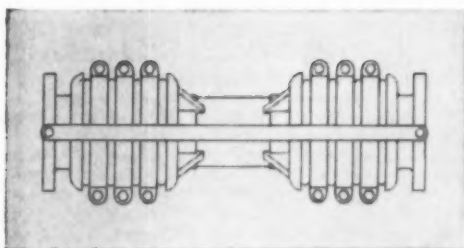
The majority of the companies queried stated that in 1953 they had hired between 76 and 100% of the men that they wanted. There was no correlation supplied between successful hiring and salaries offered.

(More News on page 24A)

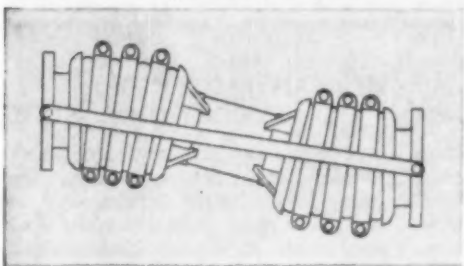
**FOR LEADERSHIP
IN EXPANSION JOINTS**



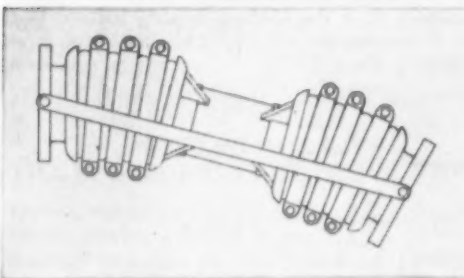
Swing with **ADSCO**



1. *Swing Joint in normal position*



2. *Swing Joint absorbing lateral motion*



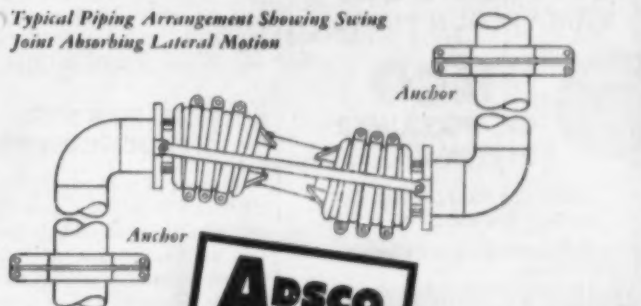
3. *Swing Joint absorbing angular rotation*

ADSCO...leading the field in expansion joints...because only ADSCO makes a complete line. This is important to you, for no other manufacturer can offer an impartial recommendation between slip and packless joints. ADSCO does not have to recommend the wrong joint simply because it does not make the right one. ADSCO *makes* the right one and can sell exactly what you need.

The Corrugflex Packless Swing Joint described on this page is an illustration of the completeness and thoroughness of ADSCO's line. Here is a joint engineered for special piping conditions. In piping arrangements where normal anchoring is impossible, as in elevated pipe lines, the Swing Joint absorbs lateral motion as shown in Drawing 2 or angular rotation as shown in Drawing 3. In the Swing Joint, the bars absorb the thrust of the line.

Whatever the problem, there is a specific ADSCO joint to solve it. Call an ADSCO representative or write for further details.

Typical Piping Arrangement Showing Swing Joint Absorbing Lateral Motion



EXPANSION JOINTS
HEAT EXCHANGERS
STEAM TRAPS

STRAINERS
SEPARATORS
METERS

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NORTH TONAWANDA, NEW YORK
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 MAINTENANCE
 COSTS and BETTER
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A simple, economical and efficient method of restoring contaminated lubricating and sealing oil to the full value of **NEW OIL**. The HILCO will produce and maintain oil free of solids, gums, water and gases in a continuous, all-electric, automatic operation.

**Be SURE of clean oil in your
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DAVISON OPENS FIRST UNIT IN FLORIDA TRIPLE SUPERPHOSPHATE PLANT



View of the sulfuric acid production unit at the \$12 million triple superphosphate plant of The Davison Chemical Corp. at Bartow, Fla. Production of the acid starts in January. Designed by Monsanto Chemical Co., the unit has a daily rated capacity of 530 tons of 100% sulfuric acid a calendar day. Under the contact process the sulfur is burned to give sulfur dioxide, which is converted by catalytic contact to sulfur trioxide, which is then absorbed to give sulfuric acid. Heat developed in the reaction is used to produce steam to power much of the equipment in the entire plant.

Equipment of the acid unit includes molten sulfur filters; storage facilities for 8,400 tons of sulfur and 6,000 tons of acid as 66° B. acid; a converter (shown with the scaffolding still in place) 39 ft. high and 24 ft. in diam.; an absorbing tower (with the longer stack) 34 ft. high by 24 ft. in diam., made of steel and brick lined and packed; a sulfur cooler (with the shorter stack); and the acid cooler (boxlike structure at right).

The capacity of the triple superphosphate plant is rated at 200,000 tons annually; all of the acid output will be required in the main process initially, but later there may be a surplus for sale.

ALLIED CHEMICAL CAUSTIC PLANT ON STREAM

Chlorine-caustic soda operations have been started at the Perkins plant of the Solvay Process Division, Allied Chemical & Dye Corp., Moundsville, W. Va., according to a recent announcement. The plant utilizes salt from the deposit located under the property. It will supply chlorine for the new chlorinated-methane-products plant now being built at Moundsville for completion in the summer of 1954.

SUN OIL HAS NEW PETROCHEMICAL PLANT

A new \$15 million petrochemical plant designed to produce annually as much as 19 million gal. of benzene, 19 million gal. of toluene, and 15 million gal. of mixed xylenes was put on stream last month by the Sun Oil Co. at its Marcus Hook, Pa., refinery.

The three continuous processing steps incorporated in the new plant are superfractionation of crude oil and natural gas; reforming, by the Houdriforming process, at temperatures above 900° F. with a platinum catalyst; and purification, largely by a Dow Chemical Co.—Universal Oil Products Co. process, which is licensed by Universal.

MONSANTO OFFERS VOCATIONAL FILM

"Decision for Chemistry," Monsanto's 16-mm. sound film introducing the young student to the chemical field, is available without charge to educational institutions, clubs, and interested industrial and commercial groups. The film runs 35 min. It may be obtained from the Modern Talking Picture Service, Inc., at 45 Rockefeller Plaza, New York 20, N. Y., or any of its local branches.

SHELL OPERATES VENTURA AMMONIA PLANT

A new ammonia plant with a capacity of 150 tons a day was recently opened by Shell Chemical Corp. at Ventura, Calif. The \$10 million anhydrous ammonia unit was located here because, according to company officials, of the growing need for ammonia fertilizer in Arizona and California and of the proximity of Shell's operations in the Ventura oil field, which offer a local supply of natural gas for ammonia manufacture. Frank D. Kuenzly, formerly superintendent of Shell's Pittsburg, Calif., plant, will manage the new plant.

(More News on page 31A)

check these *added* advantages of

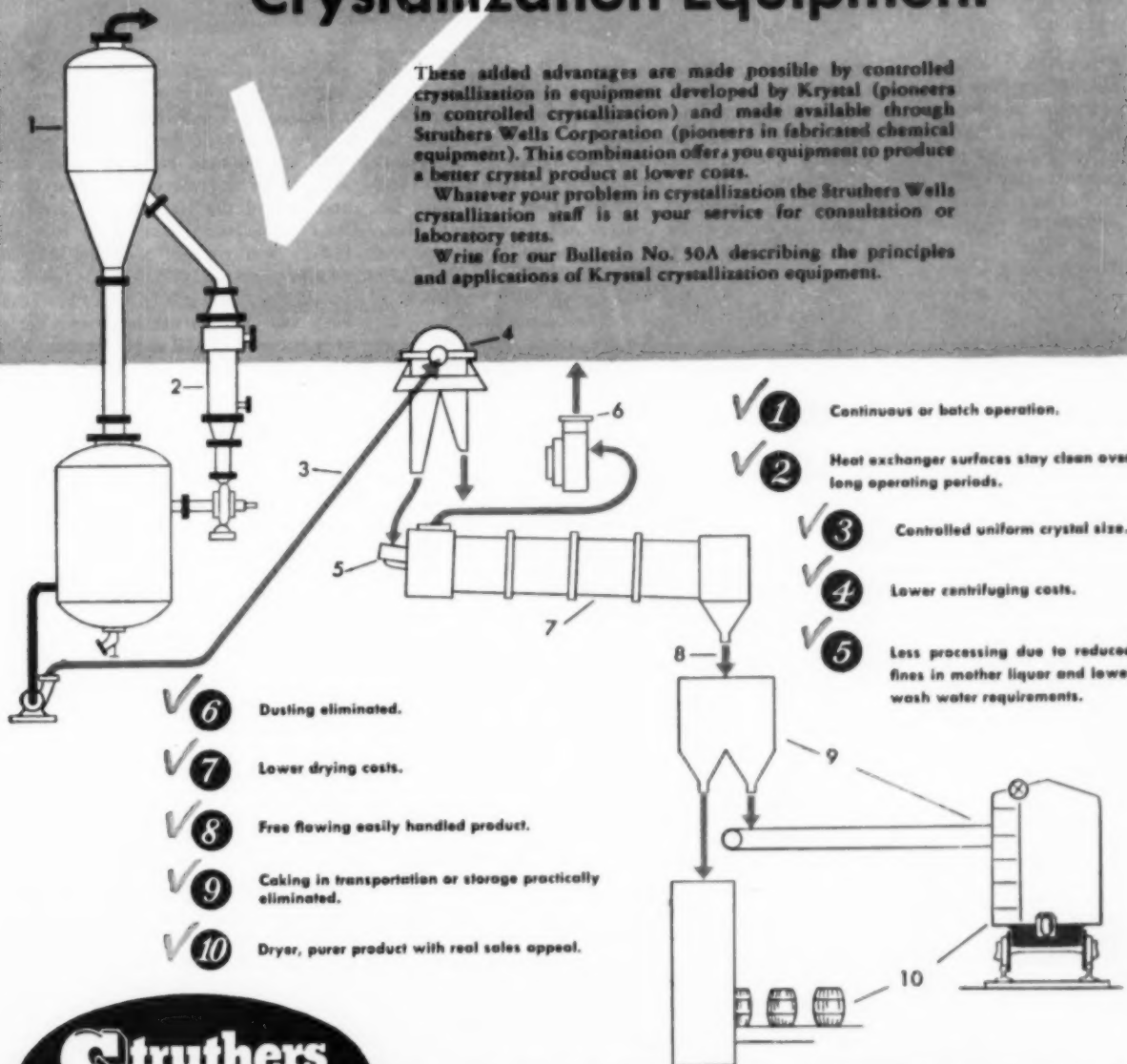
Struthers Wells **KRYSTAL**

Crystallization Equipment

These added advantages are made possible by controlled crystallization in equipment developed by Krystal (pioneers in controlled crystallization) and made available through Struthers Wells Corporation (pioneers in fabricated chemical equipment). This combination offers you equipment to produce a better crystal product at lower costs.

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Write for our Bulletin No. 30A describing the principles and applications of Krystal crystallization equipment.



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Plants at WARREN, PA. and TITUSVILLE, PA.
OFFICES IN PRINCIPAL CITIES

A. I. Ch. E. QUESTIONNAIRE

CORRELATIONS AND SUMMARY

Lloyd B. Smith, G. E. Montes and J. A. Polack

This is the fifth and final article in the current series discussing the results of the Questionnaire. It continues with a consideration of a few more correlations and concludes with a summary of the chief points brought out from this study.

Geographical location was mentioned in the previous discussion of the correlations drawn from the Questionnaire as a possible interesting basis for correlating opinions. A few of the questions from this angle have been considered, but for the most part the results were negative.

In Table 1 opinions for the Active, Associate and Junior members are tabulated for five representative geographical areas on the questions of grades of membership and nominating and voting procedures (Questions 2, 3, and 4). It is surprising that there are only minor differences in the opinions expressed over various sections of the country on the points listed for Question 2, namely "Do you feel that the requirements for Active membership are properly designed and maintained so that the attainment of this grade of membership is recognized as a real professional achievement in chemical engineering?"

There is not the same degree of uniformity in the replies to Question 3 "Are you satisfied with the present procedure for nominating Officers and Directors?" Though the differences between the responses for geographical areas are not great, a point is brought

out that in two of the areas less than 50% of the Junior members were satisfied with the nominating procedures. The condensation (Table A) of the affirmative replies illustrates this point.

The responses to Question 4 "Are you satisfied with the present procedure for electing Officers and Directors?" show a striking degree of uniformity for the Active members throughout the regions together with a little more variation on the part of the Associate members. The responses on the part of the Junior members vary from 48.9% around the Great Lakes region to 62.1% on the West Coast.

In Table 2 data are presented to show the activity of the members by geographical distribution and according to grades of membership. As a measure of this activity the participation in national and local offices and committees was chosen. There does not seem to be any significant difference in the degree of participation by geographical location.

In order to determine the comparative acceptance of C.E.P. geographically, answers to Question 6 "How well do you like C.E.P.?" are given in Table 3, according to the academic degree held by the members and also according to

geographical location. For those who like C.E.P. "very well," there is not an appreciable difference either according to degree or geographical location with the possible exception that those with Ph.D. degrees on the East Coast and around the Great Lakes area are least enthusiastic. For those who like C.E.P. "well enough" a greater percentage possibly is indicated on the East Coast. For those who "do not like C.E.P. very well" the percent acceptance varies only between 24 and approximately 30% for bachelors in various sections of the country; between 17 and 26% for the masters; and 18 and 26% for the doctors in various sections chosen.

The number of members represented in these comparisons by geographical districts amounts to 3,557 or about 27% of the total membership. A recapitulation of these figures is given in Table B. Note the high percentage of Junior members in the Gulf Coast area.

Income By Occupations

A perusal of some of the written-in comments on the salary question leads to an amplification of some of the data previously presented.¹ The salary curves given were earnings according to academic degree for all occupations. A brief table (Table 3 in that article) was shown giving pertinent data for different occupations. These data have been augmented to include the information shown in Table 4 (page 44A), and illustrated in Figures 1 and 2 (page 37A). As indicated before, the management group represents the highest paid class of engineers and the teachers the lowest paid group. There is not much difference between those in Research and Development, Design, and Operation. Next to Management, Consulting and Sales appear the most lucrative. The replies to Question 26, giving the

¹ C.E.P., July, 1953, Results of National Survey Questionnaire.

(Continued on page 36A)

Table A

Geographical Areas	Junior	Associate	Active
New Jersey	46.1	71.4	76.6
Missouri, Oklahoma, Tennessee, Kentucky	51.7	63.9	83.3
California, Washington	56.5	70.0	78.3
Texas, Louisiana, Alabama	54.7	65.9	83.6
Illinois, Indiana, Michigan	46.0	55.8	80.9

Table B

	Junior Members				
	Active Members	Associate Members	Number	Per Cent	Total
New Jersey	218	28	297	54	543
Missouri, Oklahoma, Tennessee, Kentucky ..	229	36	356	57	621
California, Washington	226	50	372	57	648
Texas, Louisiana, Alabama	262	41	497	62	800
Illinois, Indiana, Michigan	319	52	474	59	945
Total	1,254	207	1,996		3,557

What's the temperature
of the basin water?

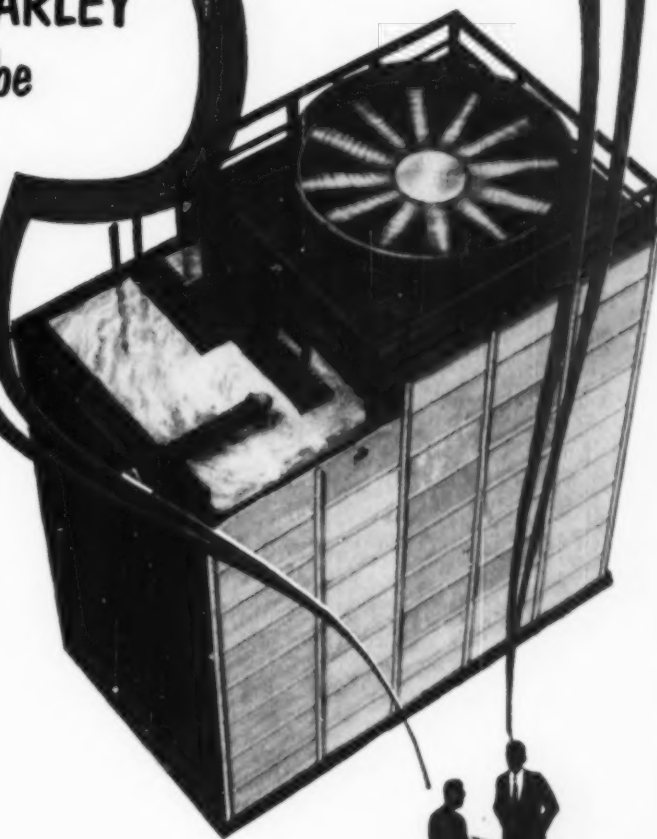
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Thermal control dictates the economy of every process operation, and the key to control is cold water — delivered consistently at design specification. Every Marley cooling tower offered today will produce that optimum result.

Built into every Marley tower is the pre-tested performance ability to do its specified job (or more) day-after-day, year-in-year-out. This is the result of 30 years of constant research and development; the result of 10,000 separate installations of Marley mechanical draft cooling towers. Today Marley has positive performance data for every tower for any location and Marley backs its knowledge with an equally positive guarantee.

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"Calculating Cooling Tower Performance from Test Data," a new Marley brochure explaining a simplified method of analyzing the actual performance of any type mechanical draft cooling tower will be available soon. May we have your name for an advance copy?

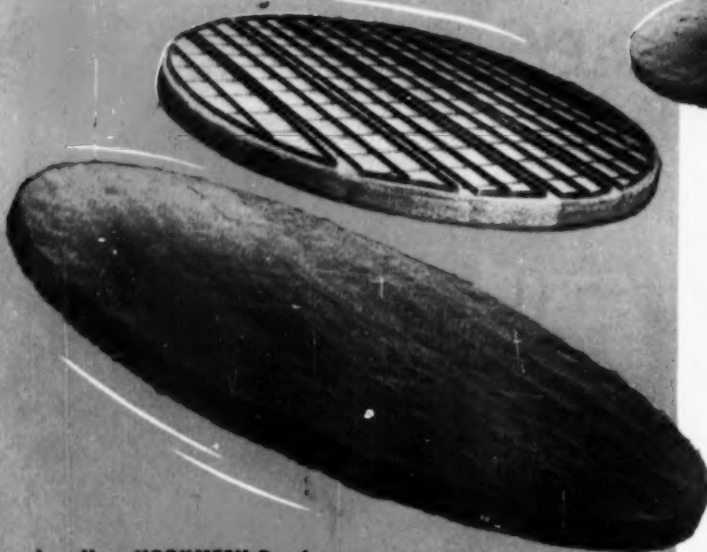


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Kansas City, Missouri



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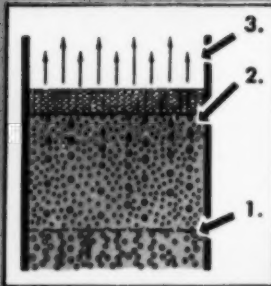


How YORKMESH Demisters work inside Vacuum Towers

Vapor disengaging from liquid creates fine liquid droplets which are carried as entrainment by the vapor stream.

The liquid droplets impinge on the fine wire surfaces of YORKMESH, and are coalesced into large drops which run down and fall off the YORKMESH.

The vapor is now dry. It has been entirely freed from entrained liquid. Thus a clean gas-oil goes to the catalytic cracker.



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- Higher vapor velocities can be used.
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- Entrainment losses are eliminated.
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Fits panel space only $2\frac{3}{8}$ " x $5\frac{3}{8}$ " yet with $5\frac{3}{4}$ " long, readable scale in keeping with $\frac{1}{2}\%$ accuracy.

Unique, new "graphic guides" mark high/low operating range, are adjustably mounted on scale drum and carry switch trippers to actuate alarms or take emergency action. Rotating drum dial and fixed reading point permit large, easily read figures and open, uniform scale. Building block construction of Ratographic indicators permits field addition of alarms and guides to the basic precision pneumatic indicator. Illustrated are two indicators which form a control selector station accessory for remotely mounted controllers.



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STAYNEW

LIQUID FILTERS

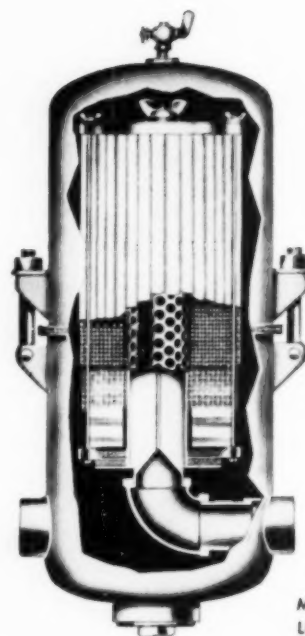
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PRACTICALLY any liquid can be efficiently and economically filtered by a Staynew Liquid Filter. They are designed for adaptation to virtually any space requirement or any arrangement of inlet and outlet connections. All known types of filtering media are available to provide any degree of efficiency for any specific problem, or for use regardless of temperature, pressure or corrosion requirement. All units can be constructed according to the API-ASME and the various ASME Code specifications. Staynew Model ELS liquid filters are available in many types of materials other than regular steel, such as stainless steel, monel, herculoy and other non-corrosive materials.

PARTIAL LIST OF LIQUIDS THAT CAN BE FILTERED BY STAYNEW LIQUID FILTERS

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Acids	Enamels	Naphtha
Adhesives	Ethanolamine	Paint
Alcohols	Ethylamine	Pharmaceuticals
Alkalis	Extracts	Propylene
Ammonia	Flameproofing	Quenching Oils
Asphalt	Solutions	Resins
Benzene	Fuel Oil	Rubber Cements
Benzine	Furniture Polish	Sizing
Beverages	Gasoline	Soap
Butane	Glue	Solvents
Casein	Greases	Steam Condensate
Castor Oil	Gums	Syrups
Caustic	Hydraulic Fluids	Tar
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A.E.C. FELLOWSHIPS IN INDUSTRIAL HEALTH

U. S. Atomic Energy Commission Fellowships in radiological physics and industrial hygiene are being offered for 1954-55 to applicants who have at least a bachelor's degree in engineering, physics, or chemistry.

The industrial hygiene fellowship program supports a limited number of individuals who study for the master's degree in this field at the Harvard University School of Public Health and the University of Pittsburgh Graduate School of Public Health.

Radiological physics fellowships are maintained at Vanderbilt University and Oak Ridge National Laboratory, at the University of Rochester and Brookhaven National Laboratory, and at the University of Washington and Hanford Works. In each case 9 months of course work at the university is followed by 3 months of additional study and field training at the cooperating A.E.C. installation. Up to 25 fellows may be appointed in each of the three programs.

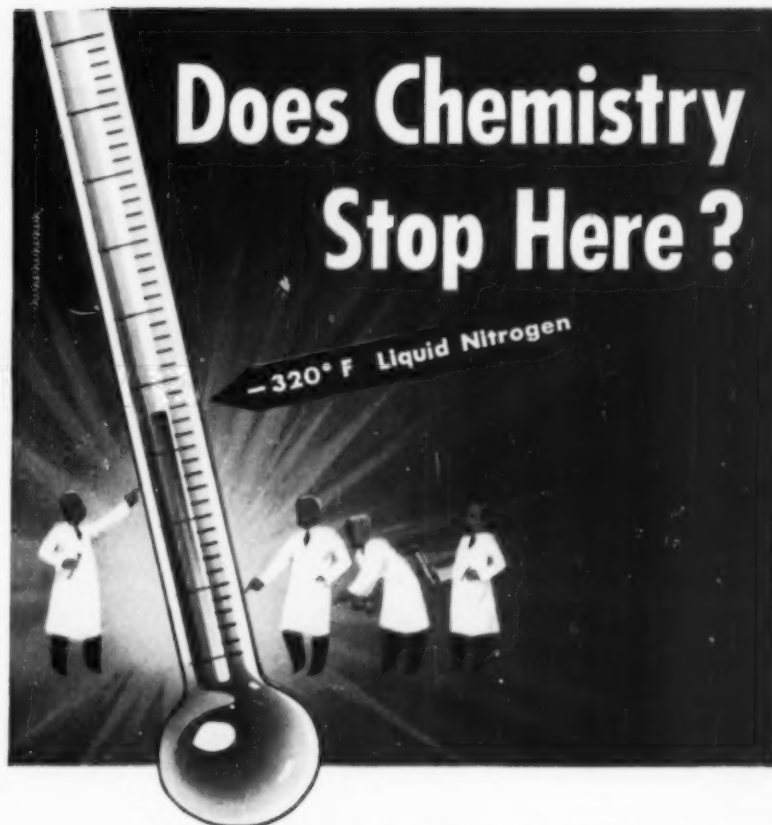
Basic stipend for both fellowships is \$1,600 with an allowance of \$350 for a spouse and \$350 for each dependent child. Tuition and laboratory fees are paid. Industrial hygiene fellows may receive an additional allowance of \$200 if they have already completed a year of graduate study or appropriate work experience in this field.

FREEPORT OPENS UNDER- WATER SULFUR MINE

Production has started at the new sulfur mine of the Freeport Sulphur Co. at Garden Island Bay, La., the company announced last month. At peak operation the mine is expected to yield 500,000 long tons annually from a salt dome deposit beneath the bay near the mouth of the Mississippi River.

To melt the sulfur, which is embedded in the caprock of the dome 1,750 to 1,850 ft. below the surface, 3,500,000 gal. of superheated water (325° F.) are pumped into the deposit every 24 hr. The water used in this operation is removed from the Mississippi River when salt intrusion from the gulf is at its lowest—usually from February to June—and is stored in two earthen reservoirs that hold nearly 1,000,000,000 gal. Pipe lines carry the heated water from a power plant, located nearly a mile from the mining area. The molten sulfur, freed of air, is pumped directly into insulated tank barges and transported to Port Sulphur for storage.

(More News on page 34A)



Normally when we think of chemistry, we think of chemical activity at room temperature and above. Yet it is possible that important anomalous behavior will appear in a very small temperature interval . . . perhaps near Absolute Zero.

Although research near absolute zero (-460° F) is relatively new, it is contributing daily to the metallurgists' understanding of the properties of metals . . . And physicists have already discovered promising low-temperature phenomena, such as superconductivity, and are now looking toward their practical application.

At present, low-temperature chemistry is mostly an interesting combination of words. But this is changing. Chemicals which are extremely reactive at ambient temperature may conceivably be stabilized at low temperature. Knowledge of what happens at extreme low temperature can be of particular value to chemists as a key to the explanation of high-temperature reactions.

Today, facilities for extreme low temperature are part of a well-equipped laboratory for virtually all fields of research. Write for descriptions of low-temperature equipment and applications—Bulletin CEP 22-7.

The ADL Collapsing Helium Cryostat made by Arthur D. Little, Inc. is the basic tool in Cryogenic research. It liquefies helium and maintains a test chamber from normal room temperature to within two degrees of Absolute Zero.



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CONTROL AIR CHECK:

front-mounted gauge indicates air pressure to control valve.

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direct or reverse acting pneumatic control—either on-off or proportional action.

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A new, low-cost temperature controller *from Honeywell*

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bulbs covers literally hundreds of control applications throughout industry.

In spite of its low price, this controller is a precision-built instrument which incorporates many of the long-lasting, high-quality components used in other Honeywell products. And it's backed by Honeywell's nationwide service organization, strategically located in more than 90 principal cities of the United States and Canada.

Our local sales engineer will be glad to discuss how this new controller can be applied to your own temperature problems. Call him today . . . he is as near as your phone.

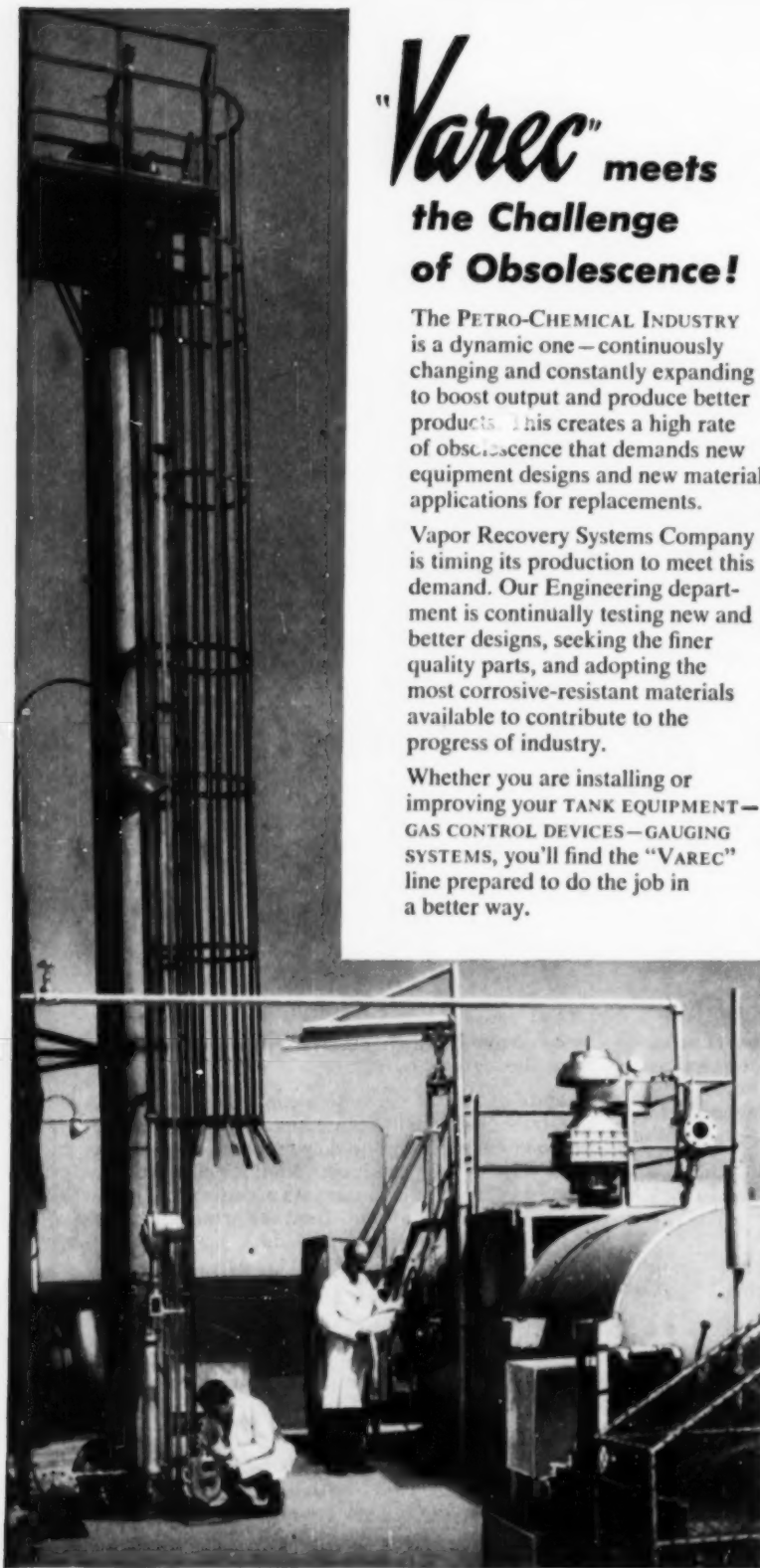
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● REFERENCE DATA: Write for your copy of new Bulletin 6401.



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NEW REFINER FOR LOW-QUALITY OILS

A new catalytic refining process for the upgrading of low-quality petroleum fractions to produce high-quality products essentially free of sulfur, nitrogen, and unstable compounds has been announced by the Union Oil Co. of California. The Unifiner, as the plant is known, will upgrade 15,750 bbl. a day of a 45° A.P.I. 1.8% sulfur gasoline for subsequent processing into a catalytic-reforming unit to produce 95- to 100-octane leaded gasoline. The latter process produces hydrogen, which in turn is utilized in the operation of the Unifiner.

The new process removes essentially all the sulfur and nitrogen as hydrogen sulfide (for subsequent sulfur production) and ammonia respectively by mixing the feed stock with hydrogen recycle gas, vaporizing the mixture, and passing it through a bed of cobalt-molybdate catalyst pellets, without loss of yield, according to Fred L. Hartley, manager of the commercial development division. "The process," Mr. Hartley said, "is applicable to the treatment of poor-quality gasolines, diesel oil and burner fuel products for sales, and the preparation of heavier gas oil fractions for subsequent catalytic cracking."

U.P.A.D.I. WILL MEET IN BRAZIL IN 1954

The third convention of the Pan-American Federation of Engineering Associations (U.P.A.D.I.) will be held in Sao Paulo, Brazil, from Aug. 3 to 13, 1954. The dates will enable engineers also to attend the World Power Conference.

The main objective of the organization is the establishment of good relations and understanding among engineers of the Americas. Toward this objective the members at the conference will continue their work on developing standards of practice and professional ethics and through the committee on technical studies will discuss methods of exchanging information. The A.I.Ch.E. is represented in U.P.A.D.I. through the Engineers Joint Council.

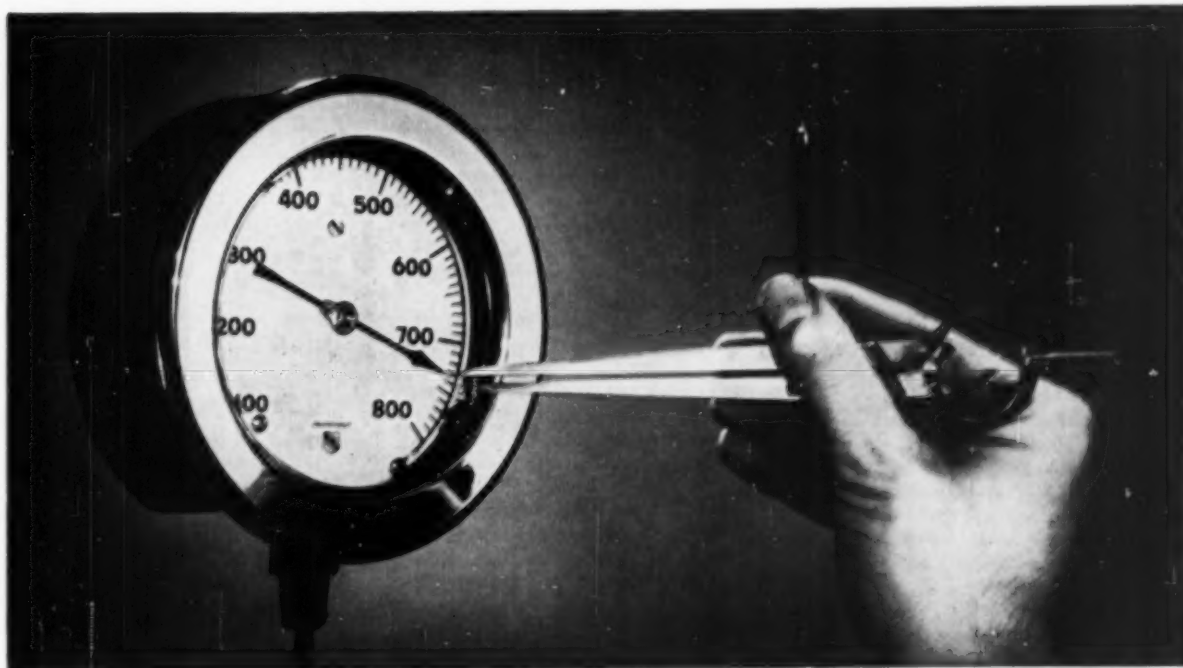
Host for the convention will be the Brazilian Federation of Engineering Associations. Opportunities will be provided for tours to sites of interest, including a complete swing around South America.

Information about the organization and the convention may be secured from U.P.A.D.I., Box 40, Midtown Station, New York 18, N. Y.

(More News on page 42A)

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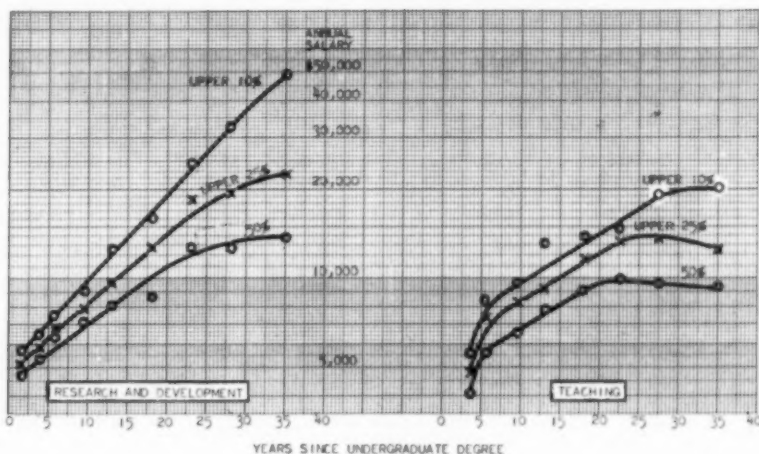


Fig. 1.

number in each occupation, are summarized in the I.B.M. card count (See Table C).

Table C

Research and Development	2,525
Design, etc.	1,132
Operation, etc.	1,806
Teaching	367
Consulting	196
Economics, etc.	164
Sales	389
Placement, Training, etc.	31
Management	865
Special Services	67
Other fields	162
Unclassified (I.B.M. rejects)	77
Total	7,801

SUMMARY

A reflection on the results of the Questionnaire leads to at least one important and significant conclusion, i.e., A.I.Ch.E. members have a great deal of interest in the affairs of the Institute. The 65% response to the Questionnaire, the large number of write-ins, and the quality of the write-ins are evidence of this interest.

The comments received were, for the most part, sincere and constructive. Some reveal areas of concern that need further study. Others raise controversial questions that may require an additional Questionnaire (much shorter and simpler) to throw further light on the issues. On the whole, one gains the impression that the members of the Institute are satisfied with their society, with their magazine, and with their profession. But not too satisfied! There are sizable, active, and articulate minorities (apparently not the same groups on all questions) who have a healthy and constructive disregard for smugness in the status quo. The character of the suggestions offered reveals this. Some may be right and some may be wrong, but most of them are interesting and many may have the germs of real improvements.

Five of the most controversial subjects are (1) grades of membership and nominating and election procedures, (2) C.E.P., (3) local sections and local meetings, (4) economic status of engineers, and (5) national meetings. Other topics that evoked comments were

(6) public relations, (7) liberal arts, and (8) licensing of engineers. Then there were miscellaneous comments, many of which were stimulating and may be useful.

The main points brought out in the discussions, tied in with the numerical replies to the questions, are summarized as follows:

1. Grades of Membership—Nominating and Voting Procedures

Question 2 asked, "Do you feel that the requirements for Active membership are properly designed and maintained so that the attainment of this grade of membership is recognized as a real professional achievement in chemical engineering?" The over-all replies to this question were 4,995 (64.8%) in the yes column, 1,191 (15.5%) no's, 943 (12.2%) who were undecided and 581 (7.5%) who didn't know the requirements. Though 5,000 members felt that the requirements for Active membership were properly designed and maintained, further analysis revealed that about 45% of these replies were from Active members, around 49% were from Junior members and approximately 6% from Associate members. Considering a membership of 12,000, there is room here for a greater difference of opinion than the favorable responses would indicate.

Questions 3 and 4 asked if the members were satisfied with nominating and electing procedures for officers and directors of the Institute. The direct replies indicated that 64% were satisfied with nominating procedures and 67.7% were satisfied with the methods for electing. A further analysis of these two questions was made by grade of membership and a somewhat different picture was presented. As one might assume from the specifications in the procedures, 81.2% of the Active members were satisfied with the status quo on nominating and 87.7% on electing. The Associate members followed with 292 or 64.7% in the yes column for nominating and 307 or 76.5% for election procedures. However, less than half of the Junior membership (2,127 or 49.6%) were satisfied with nominating procedures, but 54.1% were satisfied with election methods. A study of the write-ins indicates that there is a considerable degree of dissatisfaction in this group. Surprisingly enough, this picture changed slightly when viewed from five distinct and typical geographical areas. A disturbing fact was revealed in the replies to these questions, i.e., 23.7% of those replying did not know the methods for nominating; 36% or 1,546 Junior members did not know the election procedures, including 1,256 or 29.3% of the Junior members. On a

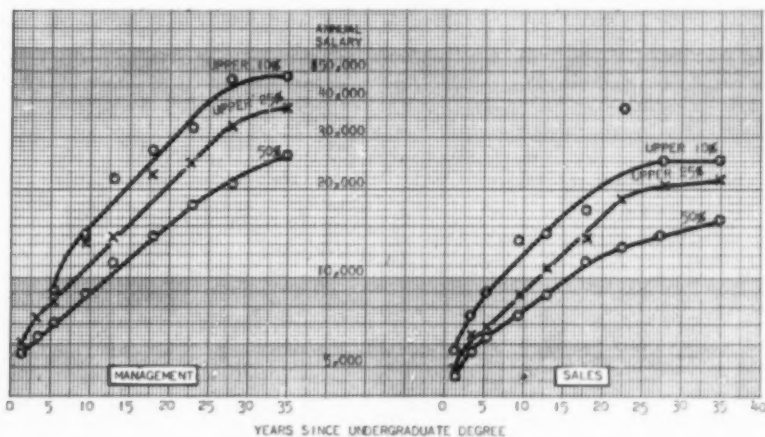


Fig. 2.

Table 2.—Question 21 (Membership Grade) vs. Questions 29 and 30

Question 29: Are you, or have you been, an officer, director or committee member in the National A.I.Ch.E.?

Question 30: Are you, or have you been, an officer or committee member in your Local Section?

Active Members				Associate Members				Junior Members				
Question 29 National Level		Question 30 Local Level		Question 29 National Level		Question 30 Local Level		Question 29 National Level		Question 30 Local Level		
Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	
New Jersey												
Yes	22	10.1	51	23.4	..	4	14.3	3	0.7	34	11.5	
No	194	89.0	165	75.7	28	100	24	85.7	291	98.3	262	88.5
Rejects	2	0.9	2	0.9	..	..	..	..	..	..	..	..
Total	218	100.0	218	100.0	28	100	28	100.0	296	100.0	296	100.0
Missouri—Oklahoma—Tennessee—Kentucky												
Yes	32	14.0	101	44.1	..	13	36.1	15	4.2	85	23.9	
No	196	85.6	125	54.6	36	100	23	63.9	340	95.5	268	75.3
Rejects	1	0.4	3	1.3	..	..	..	1	0.3	3	0.8	
Total	229	100.0	229	100.0	36	100	36	100.0	356	100.0	356	100.0
California—Washington												
Yes	20	8.8	94	41.6	2	4.0	6	12.0	8	2.2	48	12.9
No	203	89.8	132	58.4	48	96.0	44	88.0	364	97.8	323	86.8
Rejects	3	1.4	..	..	..	..	..	..	..	1	0.3	
Total	226	100.0	226	100.0	50	100.0	50	100.0	372	100.0	372	100.0
Texas—Louisiana—Alabama												
Yes	28	10.7	106	40.5	1	2.4	7	17.1	7	1.4	104	20.7
No	228	87.0	148	56.5	39	95.2	33	80.5	494	98.2	394	78.3
Rejects	6	2.3	8	3.0	1	2.4	1	2.4	2	.4	5	1.0
Total	262	100.0	262	100.0	41	100.0	41	100.0	503	100.0	503	100.0
Illinois—Indiana—Michigan												
Yes	44	13.8	92	28.6	1	1.9	1	1.9	11	2.3	78	16.5
No	271	85.0	223	69.9	50	96.2	15	28.6	462	97.5	392	82.7
Rejects	4	1.2	4	1.3	1	1.9	36	69.3	1	0.2	4	0.8
Total	319	100.0	319	100.0	52	100.0	52	100.0	474	100.0	474	100.0

complete membership basis, even assuming no similar tendency on the part of those who did not return the Questionnaire, the figures above mean at least $1,819/12,087=15.1\%$ of the Institute members are ignorant of the nominating methods and $1,387/12,087=11.5\%$ do not know the election procedures. The need for better intramural relations and communications seems imperative.

The questions of membership grades and voting were reflected in the number of write-ins. More than 900 comments were received in this field. The following comments are selected from some of the more constructive ones:

The terms Junior and Associate denote something less than a chemical engineer—tend to lower one professionally.

Eliminate Junior membership or change present classifications of Junior to Active, Associate as is, and Active to Senior.

Reserve the Associate membership rank to those on the fringes of the profession.

Suggest Life Memberships to anyone over 60 who has been a member at least 25 years.

Decrease the conversion age from Junior to Active membership to 30 years of age.

Believe more credit should be given for teaching chemical engineering in the evaluation of data for Active membership.

Responsible charge requirement for Active membership is no guarantee of professional attainment, but rather of management status.

Feel that some regional basis for at least half the directors should be adopted.

Not satisfied with the method of nominating and electing officers since only Active members participate—yet the A.I.Ch.E. is apparently supported to a very large extent by the dues of Junior members who have no voice in Institute policies.

It is the belief of the committee that these comments contain the essence of most of the dissatisfaction in this field, and also suggest means for improving the regulations and practices of the Institute so as to reduce or remove much of the cause for dissatisfaction.

2. Chemical Engineering Progress

The Questionnaire started off by asking the reader's major preference of subject matter for A.I.Ch.E. meetings and indirectly for C.E.P. The replies showed:

1,559 preferred fundamentals
3,689 preferred practical aspects
852 preferred commercial aspects
840 preferred managerial problems
650 had no preference.

Through all the maze of figures and comments these results stand out as a beacon to guide the editor. Much of the rest is contradiction and confusion. There were more than 1,500 written-in comments concerned with C.E.P. This magazine is the front window of the Institute and people want to suggest what goes into it.

Question 6 asked directly, "How well do you like C.E.P.?" The responses, predominantly favorable, were as follows:

		%
a. Very well	1,360	17.6
b. Well enough	4,228	55.0
c. Not very well	1,868	24.2
d. Not at all	137	1.7
e. Undecided	118	1.5
Total	7,711	100.0

Three correlations were made with Question 6 and other questions in an effort to obtain more light on these preferences.

a. Correlation with Question 17—academic degree—showed no significant differences according to the college degree obtained.

b. Correlation with Question 26—type of occupation—did show a variety of preferences, summarized in Table D.

(Continued on page 40A)

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PUMP "I"						YES			YES	1 PINT MANUAL	
PUMP "J"	EXTRA CHARGE			YES	YES	YES	YES		YES	YES	

NOTE: This information taken from available price book and printed literature.

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Table 3.—Question 6 ("How Well Do You Like 'CEP'") vs. Question 17 (Academic Degrees) By Geographical Areas

	No Degree		Bachelor's Degree		Master's Degree		Ph.D.		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Question 6										
New Jersey										
Rejects	..	..	..	..	1	0.6	1	1	2	0.4
Very well	1	..	36	13.4	28	16.8	10	10	75	13.9
Well enough	2	..	143	53.4	103	61.8	64	64	312	57.9
Not very well	1	..	82	30.6	32	19.	23	23	138	25.6
Not at all	..	..	4	1.5	1	0.6	..	..	5	0.9
Undecided	..	..	3	1.1	2	1.2	2	2	7	1.3
Total	4	..	268	100.0	167	100.0	100	100	539	100.0
Question 6										
Missouri—Oklahoma—Tennessee—Kentucky										
Rejects	..	..	4	1.2	..	..	..	..	4	0.6
Very well	1	..	53	15.3	27	15.3	20	21.1	101	16.2
Well enough	3	..	172	49.7	93	52.5	53	55.8	321	51.6
Not very well	..	..	100	28.9	47	26.6	18	18.9	165	26.5
Not at all	..	..	13	3.7	8	4.5	4	4.2	25	4.1
Undecided	..	..	4	1.2	2	1.1	..	..	6	1.0
Total	4	..	346	100.0	177	100.0	95	100.0	622	100.0
Question 6										
California—Washington										
Rejects	..	..	1	0.3	..	..	..	..	1	.2
Very well	4	..	52	16.1	43	20.5	22	20.8	121	18.7
Well enough	3	..	177	54.8	126	60.0	54	50.9	360	55.6
Not very well	1	..	82	25.4	37	17.6	28	26.4	148	22.8
Not at all	..	..	5	1.6	1	0.5	2	1.9	8	1.2
Undecided	1	..	6	1.8	3	1.4	..	..	10	1.5
Total	9	..	323	100.0	210	100.0	106	100.0	648	100.0
Question 6										
Texas—Louisiana—Alabama										
Rejects	..	..	1	0.2	2	0.9	1	0.9	4	0.5
Very well	1	..	84	17.9	43	19.5	23	20.2	151	18.8
Well enough	1	..	255	54.6	120	54.3	62	54.4	438	54.4
Not very well	..	..	113	24.1	46	20.8	25	21.9	184	22.9
Not at all	..	..	6	1.3	7	3.2	2	1.7	15	1.9
Undecided	..	..	9	1.9	3	1.3	1	0.9	13	1.5
Total	2	..	468	100.0	221	100.0	114	100.0	805	100.0
Question 6										
Illinois—Indiana—Michigan										
Rejects	..	..	1	0.2	..	..	2	1.6	3	0.4
Very well	4	..	69	15.3	52	20.1	13	10.2	138	16.3
Well enough	5	..	250	55.4	148	57.4	76	59.9	479	56.6
Not very well	1	..	114	25.3	51	19.8	30	23.6	196	23.2
Not at all	..	..	11	2.4	4	1.5	4	3.1	19	2.2
Undecided	..	..	6	1.4	3	1.2	2	1.6	11	1.3
Total	10	..	451	100.0	258	100.0	127	100.0	846	100.0

The numerous written-in comments on C.E.P. were for the most part contradictory but the following have been selected as those of the type frequently repeated.

The editors of C.E.P. should continue, but with renewed vigor to eliminate that type of paper which offers nothing except a work-out in mental gymnastics.

Would enjoy seeing more articles relating to the practical aspects, say 50-50, and provide reprints of technical articles for a nominal fee with only abstracts appearing in C.E.P.

Is there a way to simplify subject matter in C.E.P. so that it can be read and understood by the average chemical engineer? Several of my chemical engineer friends feel as I do on this point. Most of the subjects are up in the "stratosphere" for us.

C.E.P. should publish articles dealing with other sciences (electronics, physics, chemistry and mathematics) so that pertinent develop-

(Continued on page 44A)

Table D

Those who said very well	Those who said well enough	Those who said not very well
%	%	%
28.5 of consultants	66.1 of managers	32.7 of economists
21.2 of designers	60.5 of the misc'l groups	29.7 of plant operators
19.4 of teachers	58.6 of designers	28.1 of sales engineers
16.9 of res. & dev. groups	57.4 of res. & dev. groups	27.3 of managers
15.4 of plant operators	56.0 of teachers	24.8 of consultants
15.2 of sales engineers	54.3 of the economists	24.7 of misc'l groups
11.7 of misc'l groups	52.3 of sales engineers	22.7 of res. & dev. groups
9.3 of economists	51.5 of plant operators	21.3 of teachers
1.3 of managers	41.5 of consultants	18.2 of the designers
c. Correlation with Question 27 "What is your relationship to your main business?" also revealed significant differences as follows:		
Those who said very well	Those who said well enough	Those who said not very well
%	%	%
27.6 of self-employed	55.4 emp. of private firms	27.3 of Fed. Gov't emp.
20.2 of teachers	54.8 of teachers	26.0 of self-employed
18.8 of Fed. Gov't emp.	49.3 of Fed. Gov't emp.	24.4 of private firm emp.
17.1 of private firm or corporation employees	42.5 of self-employed	22.1 of teachers.

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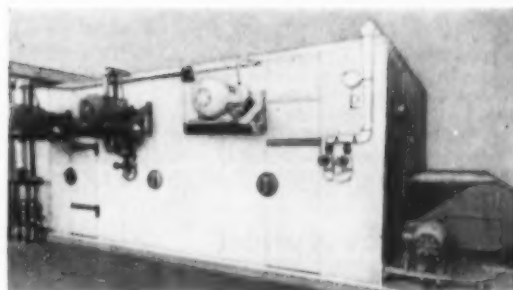
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Eduard Farber, Ph.D.

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MONSANTO COMPANY TO EMPHASIZE ENGINEERING NEEDS

A new division created to answer Monsanto's need for "a more dynamic, progressive technical force," according to President Charles Allen Thomas, appeared in the realignment of Monsanto Chemical Co. that took place on January 1. The new division, known as the Research and Engineering Division and headed by J. R. Mares, former general manager of the Texas Division, embraces functions of the general engineering department, the central research department, and the engineering sales department of the Organic Chemicals Division. Fundamental research in engineering principles will be undertaken immediately, in addition to the engineering activities of the other divisions, said Mr. Thomas, who added that plans are also being laid to install a small construction group within the Research and Engineering Division to build equipment for processes developed at Monsanto and licensed to other companies. The new division is the concern on top management level, of Carroll A. Hochwalt, functional vice-president of research, development, and engineering. He will be assisted on special projects by William T. Nichols, who has been directing the general engineering department.

Other Divisions

The over-all realignment (Monsanto's first in fifteen years), of which the new division is one result, was inspired in part, President Thomas said, by the diversity of the company's production. As previously announced, the new division line-up is based on products rather than on the former geographical distribution. Accordingly, the Western, Texas, and Merrimac divisions have been discontinued in line with what President Thomas describes as a "cardinal principle . . . that two or more divisions can operate in the same location." The six new operating divisions are as follows:

The Inorganic Chemicals Division, formerly the Phosphate Division, operates the Phosphate Division plants at Soda Springs, Idaho; Monsanto, Tenn.; St. Louis; Trenton, Mich.; and Anniston, Ala.; and the Everett, Mass., and Camden, N. J., plants of the Merrimac Division. It is headed by J. L. Christian.

The Organic Chemicals Division continues operating its plants at St. Louis; Monsanto, Ill.; Nitro, W. Va.; and Norfolk, Va., and is taking over the operation of the Western Division plant at Avon, Calif. Head of the division is Charles H. Sommer, Jr., formerly gen-

eral manager of the Merrimac Division.

The Plastics Division continues to be headed by Robert K. Mueller; in addition to its plants at Springfield, Mass., and Port Plastics, Ohio, the division operates the Western Division plants at Long Beach, Calif.; Santa Clara, Calif.; and Seattle, Wash.; and the Texas City plant of the Texas Division.

The new Research and Engineering Division has been described above.

The Merchandising and Overseas Divisions continue without additions for the present under the leadership of Roy L. Brandenburger and Edward A. O'Neal, Jr., respectively.

Executive Responsibility

In the executive offices of the company the divisions are the concern of six executive officers. Functional vice-presidents are Felix N. Williams for manufacturing; John L. Gillis, marketing; Carroll A. Hochwalt, research, development, and engineering; Francis J. Curtis, personnel, and W. W. Schneider, general counsel. Edgar M. Queny, chairman of the board, supervises the financial aspects of the operation. Also part of the executive administration is the new position of executive vice-president, to which the board elected R. R. Cole, vice-president and director of Monsanto.

Other changes include the appointment of Irving C. Smith, former general manager of the Western Division, as assistant to the president and chairman of the budget committee and the election of four division general managers as vice-presidents: Roy L. Brandenburger, Edward A. O'Neal, Jr., Robert K. Mueller, and Charles H. Sommer, Jr. Regional vice-presidents are Edward W. Gamble, Jr., and Victor E. Williams.

Staff Revisions

The staff departments also have been realigned, there now being eight instead of the former ten: Accounting, Advertising and Public Relations, General Development and Patent, Personnel Relations, Law, Medical, Purchasing and Traffic, and Treasury.

Policy

The policy direction of the company remains in the hands of the Board of Directors, with its Executive and Finance committees, membership of which remains the same. Headquarters, including that for all general managers and staff-department heads, is St. Louis.

WESTVACO SPLITS INTO TWO DIVISIONS

Separation of the Westvaco Chemical Division of Food Machinery and Chemical Corp., New York, into two separate operating divisions, Westvaco Chlor-Alkali Division and Westvaco Mineral Products Division, was announced last month.

Westvaco Mineral Products will be responsible for phosphorus, phosphates, barium chemicals, and magnesium chemicals. W. N. Williams will be president of this division. The Chlor-Alkali Division will be responsible for chlorine, caustic soda, soda ash, chlorinated chemicals, and carbon bisulfide under the presidency of Franklin Farley. Both divisions will report to Ernest Hart, executive vice-president, Chemical Divisions, Food Machinery and Chemical Corp.

CARBIDE AND CARBON CHEMICALS WINS AWARD

"The shortage that we need to be afraid of is not so much that of resources as it is of resourcefulness," said William Chapman Foster, president of the Manufacturing Chemists' Association, in a speech at a recent dinner at which the Carbide and Carbon Chemicals Co. received the Chemical Engineering Achievement award from Chemical Engineering for a high-pressure hydrogenation process that produces chemicals directly from coal.

In lauding this new source of aromatics, Mr. Foster cited it as an illustration of his thesis that the technological resourcefulness of the United States is its greatest contribution to civilization. The much-feared shortage of natural resources may, he said, prove to be a blessing if it provokes more efficient utilization of present materials and utilization of what at present is not employed.

Calling Carbide and Carbon Chemicals' achievement "dramatic evidence of scientific skill" and "a demonstration of management vision in investing some \$20,000,000 in pioneering a process," Mr. Foster stated that this investment was "the only major private money spent on development of coal hydrogenation in the past 40 years. . . . It is an example that I herewith commend to the Atomic Energy Commission and to Congress, as the most promising way to move forward in developing atomic energy for peacetime uses."

Presentation of the award was made by Walter G. Whitman, head of the chemical engineering department at Massachusetts Institute of Technology.

(More News on page 56A)

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Table 4.—Salary Curves for Various Occupations

Years since under- graduate degree	Upper 10%		Upper 25%		50 %		Upper 10%		Upper 25%		50 %	
	No. of Replies	Dollars Annual	No. of Replies	Dollars Annual	No. of Replies	Dollars Annual	No. of Replies	Dollars Annual	No. of Replies	Dollars Annual	No. of Replies	Dollars Annual
Research and Development												
1 or 2 years	23	5750	56	5100	113	4650	7	5700	17	5150	35	4650
3 or 4 years	35	6500	88	5850	176	5300	12	6700	31	5900	63	5400
5 or 6 years	23	7650	58	6850	115	6100	10	7600	24	6800	48	6200
9 or 10 years	39	9000	98	7900	195	7050	20	8800	50	7950	99	7400
11 to 15 years	53	12700	133	9600	266	8150	31	10350	77	9750	155	8550
16 to 20 years	22	16000	54	12750	107	8650	14	14600	35	12900	71	10000
21 to 25 years	13	24800	32	18050	65	12900	6	21150	14	15000	28	11300
26 to 30 years	8	32500	19	19350	39	12600	3	21000	7	15000	15	11500
31 to 40 years	7	39000	17	22100	35	13900	2	20000	4	14000	8	10400
Plant Operation												
1 or 2 years	18	6560	45	5850	90	5000	..	....	..	....	..	....
3 or 4 years	27	6750	68	6100	136	5550	2	5500	5	4750	10	4000
5 or 6 years	15	7850	37	7000	75	6100	2	8500	12	7400	8	5650
9 or 10 years	29	9800	73	8000	146	7250	4	9650	11	8250	22	6550
11 to 15 years	39	13000	97	9850	194	8700	8	13000	19	9300	38	7850
16 to 20 years	16	14550	40	13000	80	10350	5	13900	12	11500	25	9000
21 to 25 years	8	21650	20	14650	41	12000	6	14800	15	13150	30	9850
26 to 30 years	3	22500	7	17500	15	12000	4	19000	9	13400	18	9500
31 to 40 years	4	25000	10	14850	19	11650	2	20000	5	12300	10	9400
Teaching												
Sales												
1 or 2 years	2	5650	4	4900	8	4650	..	....	1	6000	2	5500
3 or 4 years	3	7500	7	6550	14	5600	..	....	2	7500	4	6250
5 or 6 years	3	9000	8	6950	15	6150	2	9000	5	8500	10	7000
9 or 10 years	7	13600	17	8900	34	7500	6	14000	14	13150	29	8900
11 to 15 years	11	14000	26	10750	53	8900	20	20400	50	13950	100	11100
16 to 20 years	5	17000	13	13600	25	11300	21	27300	54	22250	107	13900
21 to 25 years	3	37500	6	18750	13	12700	10	32000	27	24300	54	17350
26 to 30 years	2	25000	3	20850	6	13750	10	47000	25	32000	50	20600
31 to 40 years	2	23750	2	21600	8	16900	10	47600	25	37000	50	25250
Management												

ments in these sciences can be used to broaden chemical engineering.

Believe C.E.P. could improve by reducing the number of articles which give extended mathematical treatment and derivations to some of the technical data offered. Although excellent for the specialist or student just out of college, I don't believe these articles are of general interest.

Suggest that C.E.P. publish a short abstract of each paper presented at regional or national meetings. The reprints should be available, at a fee.

Consideration should be given to two publications; one of a professional character without advertisement, and the other with general interest articles, news section, editorials, and advertisement.

I don't like stiff cardboard Data Service insert sheets; they interfere with turning the pages. I think more people would tear out a coupon and enclose it in an envelope.

There are enough trade journals like Chemical Engineering and C & E N floating around without depreciating C.E.P. with non-permanent material.

The Institute and C.E.P. are either unaware or largely unconcerned with the sizable number of chemical engineers who no longer calculate distillation columns.

C.E.P. should provide active employment clearing house.

There is such a variety of ideas presented in this field, and so much contradiction, that definite constructive suggestions to the editor, based on factual data, are difficult to formulate. Here may be a case where specific questions should

be organized to obtain further information in another questionnaire on the ideas brought out in this one.

3. Local Sections

One of the valuable bits of knowledge obtained from the Questionnaire was the fact that 4,953 members belonged to local sections. This amounts to 63.5% of those replying to the Questionnaire and about 41% of the membership. This group probably represents the most valuable asset of the organization and the committees feel that efforts should be extended to foster the growth and expansion of local sections.

In the comments, requests for local sections came from Florida, Delaware, Ohio (Dayton), Utah, Louisiana, Kentucky (Paducah), Oregon (Portland), Iowa (Ames or Cedar Rapids), Idaho (Idaho Falls), Illinois, South Carolina (Savannah River), New York (Syracuse), Texas (Dallas—Fort Worth), Wyoming (Worland), Canada (Toronto), Norway, Venezuela, Mexico, and France.

Several comments from sparsely populated areas regretted that no local sections were available. Perhaps state organizations with quarterly, or semiannual, meetings might be feasible for these areas as well as for other countries.

Data obtained from the questions said that the average attendance at local section meetings was 34%. There was not much difference by grade of membership

although Active members had a slightly higher record of attendance. Twice as many felt personal contacts and professional development were important at local section meetings as did those who attended because of the technical problems discussed.

A need for individual Local Section Questionnaires is evident from some of the remarks—"Would like to serve on a committee but don't know how to get started." Questions might be included asking reasons for not attending meetings, choice of program, reasons for not belonging, and similar topics. It is believed that many of the local sections would profit from such an effort, both from the information gained and from the activity required from several members.

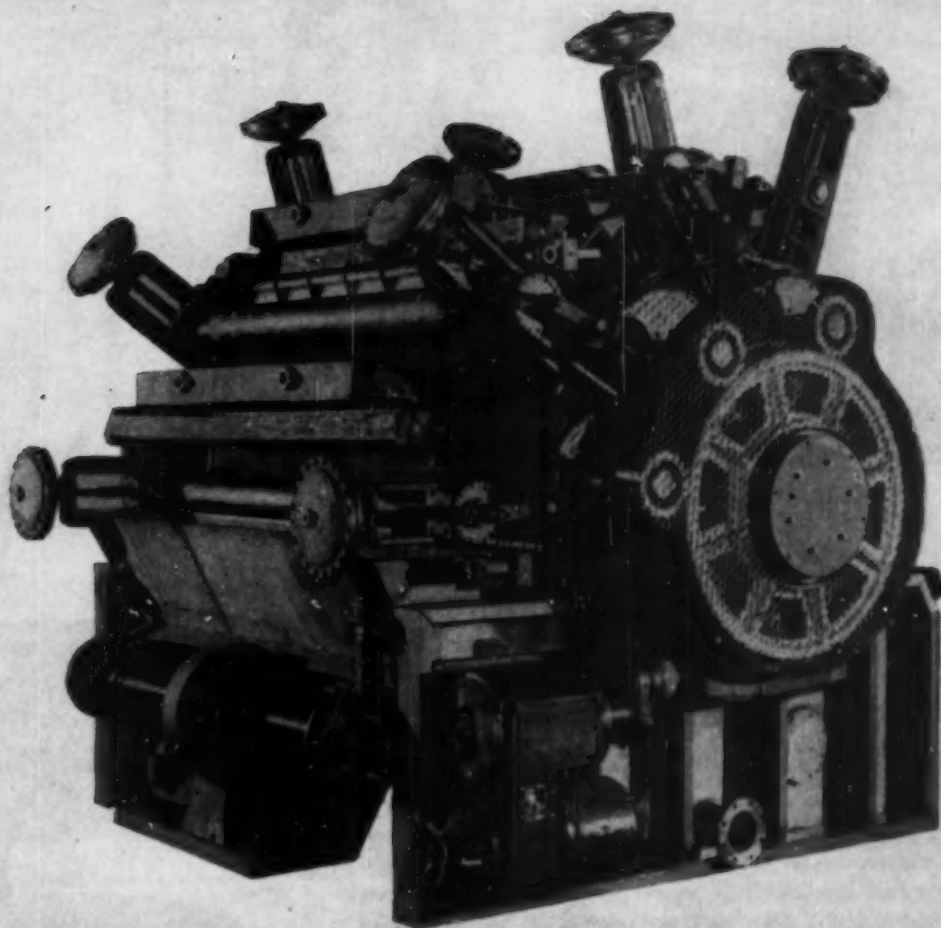
A few of the comments listed under Local Sections that might be generally useful are:

Every local section should have a Welcome Committee.

To improve attendance at local sections, suggest that greater efforts should be made to interest engineers who do not belong to the national organization. Meeting notices to these engineers as well as membership in the local section should be encouraged even though they might not care to join the national organization.

Local sections should limit membership to a maximum of 200 so that the members will derive the most benefit from the organization. If necessary have more than one local section in a densely populated area.

(Continued on page 66A)



YES! THIS TOO IS A CONTINUOUS VACUUM FILTER FOR USE IN THE PRODUCTION OF SODA ASH

PROBLEM: To dewater to as low as possible moisture content a sodium bicarbonate filter cake and to wash the cake free of ammonium chloride.

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The Vapor Recovery Systems Co.
- 35A Control for Process Heat**
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The Dow Chemical Co.
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- 41A Conveyor Type Dryers**
Increased drying capacity through system of air distribution. Small 8 ft. x 12 ft. units, to multiple-unit tunnel constructions several hundred feet long. Also batch and tunnel type truck dryers; cabinet type shelf or tray dryers; extruders and test dryers.
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- 42AL Books for Chemical Engineers**
"Fresh Water from the Ocean," "Electrolytic Manganese and Its Alloys" and "The Evolution of Chemistry."
The Ronald Press Co.

Chemical Engineering Progress

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Bowen Engineering, Inc.

56AL Propeller Pumps

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57A Metering

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Republic Flow Meters Co.

58AL Ammonia Catalysts

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(Continued on back of this insert)

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IFC	3AR	4AL	5A	6A	8AL	9A	10A	12AL
13A	14A	15A	16A	2A	21A	23A	24AL	25A
27A	28A	29A	30A	31AR	32A	34AL	35A	39A
41A	42AL	43AR	45A	46A	55A	56AL	57A	58AL
58ATR	59A	60ATL	60AB	61A	62AT	62AB	63A	64AL
64AR	65AR	66AL	67A	68AT	68AB	69AR	70AL	71A
72AL	73AR	75AR	76AL	77A	78AT	78AB	79ABL	79AR
80AL	81AT	81AB	84AT	84AB	85ABR	IBC	OBC	

Chemical Engineering Progress Data Service

Name
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Company
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January, 1954

PRODUCTS (Continued)

- 5EATR Turbo-Dryer**
Continuous, vertical, and transfer type.
Wysamont Company
- 59A Drying Problems**
Drying research laboratory.
C. G. Sargent's Sons Corp.
- 60ATL Spray Nozzles**
Data on standard and special nozzles for spraying.
Catalog.
Spraying Systems Co.
- 60AB Valves**
Quick-closing valves of cast steel with stainless steel trim. For chemical, acid, or other special services. Available in 1 in., 2 in., 3 in., 4 in., 6 in., and 8 in. pipe sizes.
Vernon Tool Co., Ltd.
- 61A Instrument System**
Controls evaporator concentration automatically.
The Foxboro Co.
- 62AT Laboratory Crushers**
Rolling ring or hammer type rotors to handle specific reduction job. Send samples for testing.
American Pulverizer Co.
- 62AB Agitator Drives**
Double and triple reduction drive unit.
Western Gear Works
- 63A Celite Filtration**
Filter cake contains more than 2,500,000 filter channels per square inch of surface. For jellies, sugar, wine, beer and antibiotics; chemicals, petroleum, and dry cleaning solvents.
Johns-Manville
- 64AL Dynel Work Clothing**
Manufacturer claims dust and chemicals won't hurt this material. Trial garment to inspect.
American Allsafe Co., Inc.
- 64AR Antifoaming Agent**
For killing foam in synthetic rubber, latices, syrups, etc.
Free sample.
Dow Corning Corp.
- 65AR Ball Joints**
Ball joints to provide tank car loading lines. Also to allow movement in piping conveying acids, alkalies, and solvents, steam, air, oil, gas, or water.
Barco Mfg. Co.
- 66AL Heat Exchangers**
For heating, cooling, process, and air conditioning.
Aerofin Corp.
- 67A Dry Crystals**
Hydrator with capacity to 8 tons of dry crystals per hour.
The Sharples Corp.
- 68AT Steam Traps**
Non-air-binding feature facilitates heat transfer in severe weather. Size 1/4 in. to 2 in.; pressures to 250 lbs.
W. H. Nicholson & Co.
- 6EAB Special Filtering Problems**
Packaged plant for continuous filtration of molten phosphorus. Also standard filtering problems. Bulletin.
R. P. Adams Co., Inc.
- 69AR Grinding and Mixing**
Cylinder mixers, mass and paste mixers, cone blenders, and ribbon mixers.
Paul O. Abbé, Inc.
- 70AL High Alloy Castings**
Carburizing fixture for ball bearings 1 1/2 in. diameter. Also, muffle for continuous strip annealing 12 ft. 6 in. long.
The Duraloy Co.
- 71A Thermal Insulation**
Line of insulations for service temperature from minus 400° F. to plus 3000° F.
Johns-Manville
- 72AL Small Volume Pumps**
Standard 1, 2, 3 or 4 feed units, jacketed units, and variable speed units.
Hills-McCanna Co.
- 73AR Mist Eliminators**
Filter out the liquid droplets by impingement and accumulation in depth. Factory cut to fit vessel dimensions and contour.
Metal Textile Corp.
- 75AR Valves to Plant**
Range of corrosion-proof chemical equipment. Permalite, pyroflex, sealon. Also tower packings. Corrosion-proof cements and coatings.
Maurice A. Knight
- 76AL Grinding Mills**
Conical, tube, tricone, rod, batch, and cylindrical mills.
Hardinge Co., Inc.
- 77A Nickel for Corrosion Resistance**
Austenitic chromium-nickel stainless steels. Mechanability, scaling resistance, resistance to corrosion.
The International Nickel Co., Inc.
- 78AT Steam Jet Ejectors**
Condensers and vacuum equipment. Corrosion resistant parts interchangeable with standard parts.
The Jet-Vac Corp.
- 78AB Plate Fabrication**
Towers, pressure vessels, general plate fabrication and heat exchangers.
Downtown Iron Works, Inc.
- 79ABL High Temperature and Refractory Equipment**
Heating and cracking units for gases and hydrocarbons.
Petrocarb Equipment, Inc.
- 79AR Spray Nozzles**
For chemical spraying, cooling, humidifying, and dehydrating.
Binks Mfg. Co.
- 80AL Pumps**
Designed for corrosive and hazardous fluids. Capacities from fractional to 20 gal./min.
Vanton Pump and Equipment Corp.
- 81AT Metal Products**
Pilot plants and complete plants. Features vacuum rectifying column—with automatic air-operated control.
Artisan Metal Products, Inc.

PRODUCTS (Continued)

BTAB Filter Facts

Book contains information for the user of filtration and fluids-handling equipment.
T. Shriver & Co., Inc.

B4AT Plasticizer Oil

Compatibility with GRS, neoprene, and buna N type rubbers.
Pan American Refining Corp.

B4AB Industrial Balances

Micrometer-poise balance for speedy determination of weight.
Ohaus Scale Corp.

ESAB Evactors

Steam jet vacuum units provide pressures ranging from a few inches to a few microns.
Croll-Reynolds Co., Inc.

IBC Controlled Volume Pumps

Bulletin presentation of pump operating principles, capacity pressure and air-consumption tables.
Milton Roy Co.

OBC Fluid Mixing

Laboratory, portable, top entering, side entering mixers.
Mixing Equipment Co., Inc.

BULLETINS

- 1 **Dispersall Mixer.** For dispersing, emulsifying, & milling in one operation, Abbé Engineering Co. Dispersall mixer applicable to fluid mixes from thin slurries to pastes. Two types milling elements; other features described in catalog. For adhesives, ceramics, chemicals, food, paint, rubber. Cutaway views, illustrations, tables.
- 2 **Hogs & Shredders.** Williams Patent Crusher & Pulverizer Co., Inc. hogs & shredders. For conversion of wood refuse into fuel. Illustrated catalog shows steps in preparation, & results. Several types, accessory equipment, cutaway views shown.
- 3 **Indicator-Controller.** Electrolytic conductivity indicator-controller. Nonrecording, self-balancing continuous indicator. Industrial Instruments, Inc.
- 4 **Screens, Presses, Dryers.** Davenport Machine & Foundry Co. Bulletin on continuous processing of semisolids. Covers presses, screens and dryers for food processors, breweries, distilleries, packers, pulp, drug, chemical industries. Illustrated, lists features; materials of construction; sizes; other pertinent data.
- 5 **PneuBin.** For uniform, noiseless feeding of stubborn materials from bins & hoppers by positive displacement, PneuBin from Gerotor May Corp. Feeds all sizes of materials; densities from 2 to 200 lb./cu.ft.
- 6 **Mechanical Apparatus.** From Servo Mechanisms, Inc. illustrated bulletin on foundation boards, mounting & bearing blocks, shafts, gears, couplings, assemblies & accessories. Diagrams, parts listing, sizes, other data.
- 7 **Motors & Generators.** D. C. motors & generators from Louis Allis Co. 1/2 to 300 hp., 1/4 to 250 kw. Details of mechanical construction shown in illustrated binder insert. Cutaway views. Section on motor-generator sets for conversion of current.
- 8 **Drumpak.** Drumpak container designed in any desired size or style. Gaylord Container Corp. Also dispensing type.
- 9 **Stuffing Box.** Taber Pump Co. folder offers hints and suggestions for selection & use of stuffing boxes. Illustrated, shows schematic drawings, gives other data.
- 10 **Gate Valve.** Seal O Ring gate valves from Grove Regulator Co. Full-opening, impassable seal, nonlubricated. Two valves in one, metal-to-metal closure special O ring seal, capable of closing line & in combination effects impassable seal.
- 11 **Nephelometers.** Issued by Coleman Instruments, Inc. booklet on nephelometry. Explains how instrument works by measuring light reflected from particles in suspension. Shows how to eliminate five out of seven steps.
- 12 **Safety Valves.** Available in Farris Engineering Corp. nozzle and seminozzle safety relief valves, internal heat exchanger. Unit incorporated in valve body without interference to other valve mechanism. Eliminates steam tracing or jacketing a valve with highly viscous lading.
- 13 **Injecto-weigh.** For automatic weigh-feeding charges of plastic material into injection molding machines Injecto-weigh from Glengarry Equipment Corp. Adjustable 1 to 100 oz.
- 14 **Ejectors.** The Jet-Vac Corp. folder on standard Jet-Vac ejectors. Steam line sizes to 1 1/4 in. Fabricated in any metal; nonmetal used for corrosive service. Tables, schematic drawings, illustrations, other details.
- 15 **Vacuum Tank.** Loose-leaf binder from Thompson Tank & Mfg. Co., Inc. includes specification sheets on each tank in line. Capacities 30 to 110 bbl. For moving liquids & semisolids from place to place. Vacuum principle permits movement of substances impossible to handle by other means.
- 16 **Depth Gauge.** Subscout, portable storage tank depth gauge from Aerco Industries. Accurate within 2%; applicable to most liquids; self-operation; no attachments required. Folder gives cutaway view plus illustrated applications.
- 17 **Control Instruments.** Bailey Meter Co. catalog covers instruments for metering & automatic control of seventeen process variables. Lists ranges, basic specifications, cutaway views, applications.
- 18 **Chemical Feed Unit.** From Philadelphia Pump & Machinery Co. packaged chemical feed unit. Self contained assembly, chemical solution tank, 50 to 100 gal., mounted above controlled capacity pumps. Completely piped, ready for installation. Sight gauge & stainless steel strainer between pump & tank. Vertical agitators available.
- 19 **Special Construction Reprints.** For design and supervision of erection of high-temperature equipment & refractory constructions including vertical retorts, etc., Petrocarb Equipment, Inc. Loose-leaf binder contains technical reprints.
- 20 **Industrial Mixers.** Vertical mixers with & without base and stuffing box. Variable speed drives 1/4 to 25 hp. Speeds variable. Steel, stainless steel, other materials. Illustrated folder. Conn and Co.
- 21 **Unit Regulator.** Self-contained unit regulator for automatic control of flow pressure. Bulletin from Askania Regulator Co. For medium-duty work in single appli-

- cations. Motor 1/4 to 1/3 hp. totally enclosed. Circulates 1 gal. oil/min. at 1,725 rev./min. Cutaway view, other illustrations and data.
- 23 **Conveyor Belt Idlers.** Link Belt Co. catalog shows more than 500 belt conveyor idlers in thirty-four types, for light, medium & heavy duty. Information on selection & spacing, based on material size to be conveyed. Schematic drawings, dimensional data.
 - 24 **Cone-Drive Gears.** Cone-Drive Gears division of Michigan Tool Co. booklet on double-enveloping worm gearing. Documents successful applications & twenty industrial classifications.
 - 25 **Laboratory Furniture.** Tour of new Dept. of Agriculture Laboratory featured in bulletin from Laboratory Construction Co. Illustrates latest design in specialized furniture & equipment. Gives descriptions.
 - 26 **Materials Handling.** Yale & Towne Mfg. Co. revised edition of "The How Book of Cost-Cutting Materials Handling," methods of analysis of materials handling.
 - 27 **Control Panels.** Central control panel, Panelgraph from Panellit, Inc. Bulletin shows typical industrial installations, panel components, control devices.
 - 28 **Measurement Instruments.** From Brush Electronics Co. a 34-page book, describing thirty-seven different instruments engineered & produced for electrical, physical, resistance-welding, textile & other measurements. For research, production & methods engineers.
 - 29 **Tubular Conveyors.** Bulletin from Hapman Conveyors, Inc., Division Hapman-Dutton Co. shows engineering & mechanical details of tubular conveyors. Describes various conveyor drive mechanisms, roller turns, vibrators, etc. Nine layouts for conveying wet or dry chemicals, food, wet spent grains, other.
 - 30 **Flexible Metal Hose.** A bulletin from Atlantic Metal Hose Co., Inc. on high pressure interlocking bronze & steel flexible hose, tar & asphalt hose, loading & unloading, plus necessary couplings. Provides full test & engineering data; lists applications.
 - 31 **Mixed-Bed Demineralizers.** Operation of mixed-bed demineralizer in production of high purity water by ion-exchange method detailed in folder from Barnstead Still & Sterilizer Co. Simplified positive regeneration system separates & remixes resins.
 - 32 **Industrial Products.** Line of centrifugal loaders, car pullers, bin level controls, etc. by Stephens-Adamson Mfg. Co. Pertinent information on each item.
 - 33 **Pump Control.** Electrically or pneumatically operated centrifugal pump recirculation control from Republic Flow Meters Co. Installation insures minimum flow through pump to prevent temperature rise. Illustrated booklet gives schematic diagram of system plus suggestions for location.
 - 34 **Blowers.** For air or gas, centrifugal-type blowers & exhausters. Billmyre blowers from Lamson Corp. illustrated & described in bulletin to indicate wide variety of uses. Technical data on agitation, vacuum cleaning, pneumatic conveying, etc.
 - 35 **Liquid Process Equipment.** Alsop Engineering Corp. line of stainless steel filters, mixers, tanks & pumps. Detailed & illustrated descriptions of each item, schematic views, tables.
 - 36 **Corrosion Protection.** Booklet from Bart Mfg. Corp. manufacturers of nickel lined steel pipe, fittings, flanges. Discusses Lectro-Clad process & uses of nickel-lined steel pipe. Descriptions of application in various fields, test results.
 - 37 **Process Pumps.** Allis-Chalmers Mfg. Co. process pumps for handling corrosive & abrasive liquors. Units in five sizes, provide capacity range 20 to 1,300 gal./min. at heads to 260 ft. Table of dimensions & range diagram.
 - 38 **Meters.** Porcelain, glass, & metal Flowrator, fluid-flow rate meters by Fischer & Porter Co. Variable-area flow principle. Bulletin describes type, dimensions, schematic drawings, etc.
 - 39 **Control Instruments.** Electronic Dynamaster potentiometers, automatic controllers, recorders, indicators. Described in Bristol Co. catalog. Specifications, details, drawings of each item.
 - 40 **Steel Weldments.** Use of steel Weldments for reduced costs & increased efficiency. Illustrated brochure from Struthers Wells Corp. lists definitions, general data, properties.
 - 41 **Vertical Pump Motors.** Hollow or solid shaft vertical pump motors for chemicals, oil, water, described & illustrated in bulletin of Louis Allis Co.
 - 42 **Insulation Tester.** Now furnished with improved case, Midget Megger insulation tester from James C. Biddle Co. Not dependent on batteries or other power. Ratings to 50 megohms, 500 v.d.c. available.
 - 43 **Sprockets & Roller Chain.** Dodge Mfg. Co. bulletin on Taper-Lock sprockets, also roller chain. Cross-section drawings, dimensions, number of teeth.
 - 44 **Laboratory Construction.** Brochure from Baton Construction Corp. on planning & construction of modern research laboratories. Ten major projects illustrated & described.
 - 45 **Glass Textiles.** Hess, Goldsmith & Co., Inc. booklet on "Glass Textiles for Industry," nineteen industries & fields in which glass textiles are used. Three basic forms discussed.
 - 46 **Bleeder Valves.** Valves for bleeding air from hydraulic systems. Republic Mfg. Co. offers four units. Many sizes, available for 1,500 lb./sq.in. service. Some to 3,000 lb./sq.in. at temperatures -65° to 180° F.
 - 47 **Electronic Weigh.** For electronically weighing tanks, bins, hoppers, Baldwin-Hamilton Corp. SR-4 load weighing system. Bulletin explains system, covers design consideration, accuracy, other engineering services. Cutaway views.
 - 48 **Low-Level Illumination Meter.** Specialties, Inc. leaflet on low level illumination meter. Accuracy in quantitative measurement of light as low as .005 ft.-c. Description, operation, specifications listed.
 - 49 **Stainless & Monel Utensils.** Pails, dippers, funnels, scoops, etc. from Metalsmiths, Division Orange Roller Bearing Co. Lists prices, gives information on special items & fabricating services.

EQUIPMENT

- 55 **Temperature Regulator.** Farris Stacon Corp. bulletin on series V self-operating temperature regulators for steam, liquids, gases. Illustrated, gives selectivity charts, principles of operation, other data.

- 56 **Plasticote.** Protection against corrosion of hot water generators & storage tanks by use of Plasticote, non-porous, insoluble lining from Metalweld, Inc. Applied by trowel to thickness of $\frac{3}{4}$ in. Provides extra insulation, reduces heat loss, etc.
- 57 **Vacuum Pump.** Pressure range 6×10^{-2} to 5×10^{-2} mm. of Hg. Consolidated Vacuum Corp. One model produces pressure 5×10^{-3} mm. Hg, operating against fore-pressure of 0.5 mm. Hg. Air-removal rate exceeding 3,000 cu.ft./min.
- 58 **Fire Equipment.** Ansul Chemical Co. wheeled extinguishers, with new nozzle & gas tube design. Dry chemical flow rate increased 30% by redesign.
- 59 **Tank Insulation.** Insulation of propane & butane storage tanks accomplished with K-20 concrete mix from Babcock & Wilcox Co., kaolin base & hydraulic setting cement binder.
- 60 **Circle Sifter.** Gyrotory sifter from Allis-Chalmers Mfg. Co. Six-sieve, all-metal unit. Handles 160 lb. laundry starch min. through 120-mesh light wire screen atop three sieves, through a 145-mesh screen on bottom three sieves.
- 61 **Explosion-Proof Mixer.** Lightning laboratory mixer, Underwriter approved, for simple fluid mixing, blending, solids suspension, gas dispersion. Also in mass- & heat-transfer studies. Handles to 50 gal. Mixing Equipment Co., Inc.
- 62 **Hand Tachometers.** The story of speed measuring by resonance set forth in illustrated booklet from James G. Biddle Co. Tells how series of tuned steel reeds can indicate speeds more accurately than other mechanical tachometers.
- 63 **Packaged Process Control.** Minneapolis-Honeywell Regulator Co. individually engineered control-systems units. Automatic control of industrial process operations. Includes recording & control instruments, etc.
- 64 **Slide Rule.** A convenient calculator for those in the metal-working industries designed by Continental Copper & Steel Industries, Inc. Available through Alloy Fabricators Division. Simple manipulation of slide computes weights of strips, sheets, bars, plates of various metals & alloys. Factors given for variety of metals.
- 65 **Valves.** Ultravalve self-lubricating, self-draining, positive sealing design valve. Reduces worker hazards & eliminates maintenance. Folder from Hammel-Dahl Co. shows various types of assemblies, gives schematic drawings, discusses other advantages.
- 66 **Film-Type Absorber.** New Karbate model falling-film type absorber from National Carbon Co. Features easy erection & maintenance, lower cost. Hydrogen chloride & other gases, no after cooler.
- 67 **Simplified Potentiometer.** From Weston Electrical Instrument Corp. booklet on new recording potentiometer interchangeable parts.
- 68 **Swivel Fittings.** Added to line of Emsco Mfg. Co. ball bearing swivel fittings for applications & pressures where schedule 40 pipe is used. Maximum pressure 1000 lb./sq.in. at 225° F. Others for pressures to 15,000 lb./sq.in. & temperatures of 750° F. Illustrated leaflet gives detailed information.
- 69, 70 **Spectrometer.** (69) New ionresonance mass spectrometer from General Electric Co. For process instrumentation requirements in the gas, petroleum, pharmaceutical, & chemical fields. Uses most recent development in mass spectrometry-ionresonance. (70) Cabinetrol a low-voltage control system. Illustrated bulletin describes system, gives reference & selection charts, other data. For all motor types to 600 hp., from central location.
- 71 **Distilled Water Valve.** For distilled water systems basic valve from Autoclave Engineers Sales Corp. Illustrated Bulletin shows schematic diagram, and variations from basic design. System lined with block tin. Availability & features of Alstan tubing & fittings.
- 72 **Electric Arc Furnaces.** For direct & submerged arc furnaces in steel mills, chemical plants, foundries & nonferrous metal refineries, Westinghouse Electric Corp. equipment. Illustrated booklet gives cutaway views, other pertinent data.
- 73 **Packing Tips.** Packing tips subject of brochure from U. S. Rubber Export Co., Ltd. Sections on care, installation, joints, lubrication, & other phases of information on mechanical packings.
- 74 **Gas Sampling Pump.** New type gas-sampling pump for use with gas analyzing equipment, from Vanton Pump Corp. No stuffing boxes, does not touch metal. Two parts in contact with fluid are of corrosion-resistant materials. Oil reservoir enables capacities from 0 to 35,000 cc./min. with discharge pressures from 0 to 35 lb./sq.in., suction lifts to 22 in. Hg.
- 75 **Dealkalizer.** American Water Softener Co. process for increasing capacity of anion exchange resins. Cycloflow valve eliminates contaminating leakage. For use in power plants, textile mills, oil refineries, etc. Leaflet.
- 76 **Karbate Centrifugal Pumps.** Types C & F centrifugal pumps of Karbate impervious graphite for the chemical industry, new with National Carbon Co. Sizes 2, 3, & 4 in. with 8 or 10 in. impellers. Capacities 5 to 1,500 gal./min. at discharge pressures to 1,000 lb./sq.in. enclosed mechanical seal coolant.
- 77 **Automatic Speed Control.** Varitrol an automatic Varidrive speed control. Operates on air pressure 60 to 100 lb./sq.in. Controlled by air cylinder using air on both sides of positive positioning piston. Positioner operates on 3 to 15 lb./sq.in. signal air & controls pilot valve regulating power air. U. S. Electrical Motors Inc.
- 78 **Diaphragm Valves.** Newly announced by Minneapolis-Honeywell Regulator Co. line of diaphragm motor control valves. Known as Series 800 & designed for use with wide-band, proportional control instruments. Includes direct- & reverse-acting, & springless diaphragm motors.
- 79 **Glass Pipe & Fittings.** Pyrex pipe & fittings. Corning Glass Works. Revised catalog includes standard stock length items, discusses physical properties. Technical information for plant engineers.
- 80 **Filling Scales.** Two new types of filling scales from Thayer Scale and Engineering Corp. For production weighing of granular, flake, or fibrous material. Automatic bag joggler available.
- 81 **Compressor Valve.** Aircheck valve for compressor discharge lines, from Pennsylvania Pump & Compressor Co. Supplements earlier valve & features accessibility for inspection. Dampens pipe-line pulsations. Available for installation on 8, 10, & 12-in. lines. Illustrated leaflet.

- 82 **Vacuum Gauge.** Developed by National Research Corp. new Pirani vacuum gauge. Features low impedance power rectifier eliminating voltage adjustments while in operation; one meter used for voltage adjustment & pressure reading; compensating element mounted inside cabinet. For electronics, plastics, & metal industries. Readings between 1,000 & 1μ pressures.
- 83 **Laboratory Equipment.** Bulletin from Mettler Equipment Corp. presents facilities. Types of equipment with specification information, other details.
- 84 **Bantam Strainer.** Merco Centrifugal Co. Bantam strainer for fast, continuous straining of oversize particles from process streams in food & chemical process industries. Small space & power requirements, prevents product contamination by continuous removal of particles. Designed for fibrous or viscous slurries & equipped with motor-driven scrapers to prevent plugging.
- 85 **Reducing Valve.** For small flow applications such as plastic molding presses, pilot plant operations, laboratory units, etc., reducing valve from Leslie Co. Four sizes, entirely enclosed, corrosion resistant metal diaphragm, interchangeable parts. Folder shows cutaway views, gives capacity tables, other data.
- 86 **Fuel Oil Heater.** Protection of boiler water against oil leaks is objective of E type safety fuel oil heater from Manning & Lewis Engineering Co. For below waterline service. Special electric element detects oil in boiler water, control box sounds alarm when fuel oil leakage occurs in preheater. Illustrated folder.
- 87 **Float Trap.** Stainless steel float trap for draining corrosive liquids from air, gas, & steam in the chemical, petrochemical, refining, textile, and other industries. Forms constant drain of liquids without escape of air or gas. For 300-lb. pressure, maximum temperature 800°, sizes $1/2$ to 2 in. V. D. Anderson Co.
- 88 **Single-Stage Turbine.** De Laval Steam Turbine Co., single-stage turbine, horsepower to 100, pressures to 300 lb./sq.in gauge, temperature to 550° F. speed to 4,000. Folder shows cutaway views, diagrams, lists features, measurements, etc.
- 89 **Midget Solenoid Valves.** Midget solenoid valves developed by General Controls Co. New series of magnetic stop valves for use with all type gases & fluids. Operates in any position, features positive shutoff, low-current consumption. Types for variety of uses.
- 90 **Computing Facilities.** Issued by Illinois Institute of Technology, on "Computer Center," a booklet which describes analog & digital equipment operated by the Computer Center, & types of problems it can solve. Problem solving service available.
- 91 **Demineralizer.** From Penfield Mfg. Co., Inc. a demineralizer equipped with special controls which enables automatic maintenance of storage tank water at known purity standard. After completion of regeneration cycle, in final rinse stage, automatic controls perform all required functions.
- 92 **Vapor Barrier Book.** Published by Insul-Mastic Corp. of America, an 80-page book, giving complete recommendations for vaporsealing insulation on low-temperature vessels. Illustrations show where & how a vaporseal coating should be applied over thermal insulation. Other pertinent information.
- 93 **Electronic Temperature Control.** Electronic temperature controller with range to cover -100 to $+600^\circ$ F. Bulletin

from Minneapolis-Honeywell Regulator Co., Brown Instruments Division gives application information, specifications, data resistance, schematic diagrams, etc.

- 94 **Compressor.** Developed by Ingersoll-Rand Co. a turbo-charged gas-engine-driven compressor. 2,000 hp. turbo-charged. Crankshaft design, compound crankpins give reduction in size & weight. Features low-heat rejection & high-temperature level.
- 95 **Wet Blasting Machine.** New with American Wheelabrator & Equipment Corp. model 30 Liquamette wet blasting machine. Bulletin carries specifications & illustrations. For precision cleaning & finishing of small parts capable of passing a $22\frac{1}{2} \times 19$ -in. opening.
- 96 **Induction Motors.** Reliance Electric & Engineering Co. new squirrel-cage induction motors. More horsepower in compact space. For 1-, $1\frac{1}{2}$ -, 2-hp. applications; frame sizes 182 & 184. Features enclosed fan-cooled motors for operation under various atmospheric conditions.

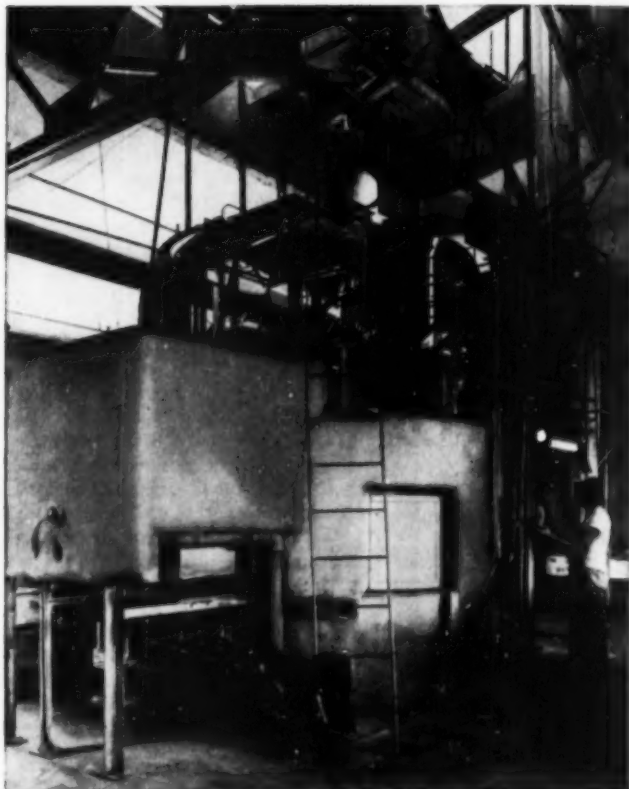
CHEMICALS

- 105 **Protective Coatings.** From Hercules Powder Co. bulletin covering thirty-five case histories of successful use of chlorinated rubber protective coatings. Includes paper mills, storage tanks, chemical & food-processing plants, etc. Application instructions, performance data, other pertinent information.
- 106 **Polyvinyl Chloride.** Technical data bulletin from Dow Chemical Co. Describes series of polyvinyl resins & applications of each type. Graphs, tables on properties of materials. For calendaring or extruding.
- 107 **Antifoam Spray.** For foam control in laboratory, pilot plant, or other processing operations, Antifoam from Dow Corning Corp. Dispersion of silicone compound in Freon, aerosol-packaged mist released by touching valve.
- 108 **Isostyre.** Styrenated dehydrated castor oil called Isostyre. Unpigmented form is similar to varnish. Woburn Chemical Corp. (N. J.) technical data sheet covers general characteristics, drying qualities.
- 109 **Teflon-Plus.** Dixon Saddle Co. Information on the use of Teflon-Plus as a frier material. Tests include more than 200 mixtures. Immediate replies on coefficient of friction & resistance to abrasion.
- 110 **Water Repellent.** Flexrock Co. bulletin on Flexseal, inorganic water repellent for brick, stucco, cement base paints, etc.
- 111 **Extrusion & Injection Molding.** Use of Kralastic in extrusion & injection molding subject of booklet by U. S. Rubber Co. Includes properties, fabricating methods, applications, & general types. Informative graphs, illustrations.
- 112 **Dimetecote.** Protective zinc coating for steel against atmospheric conditions. Applied with brush or spray. Renders cathodic protection when abuse results in break or damage. Amercoat Corp. Inailet.
- 114 **Flame Retardant.** X-12 new flame retardant from Grasselli Chemicals Dept., now in commercial production. Crystalline X-12 is water soluble & solutions are stable. Improves dye fastness.
- 115 **Teflon-Coated Materials.** New technical bulletin describing properties & applications of Teflon tetrafluoroethylene resin-coated glass fabrics, tapes, & laminates from Du Pont Co.

SPRAY DRYER PIONEER

American Lava meets difficult problem of fine blending and homogeneity by use of Bowen Spray Dryer

American Lava Produces First Spray Dried Titania Dielectric Material



Operator at the controls of Compact Bowen Spray Dryer producing titania dielectric product.



A desire for a higher quality product led American Lava to experiment with various methods of producing a finely blended homogenous titania material suitable for extrusion of special dielectric parts. Ordinary wet blending and subsequent drying previously used in this field did not produce the required uniform product.

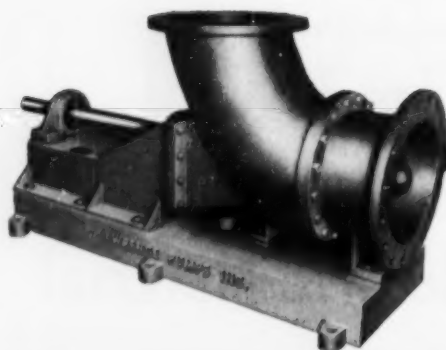
American Lava was the first to use spray drying to solve the problem. Materials are now wet blended in a ball mill and then fed to the spray dryer. A finely blended homogenous product subject to infinite control of the dielectric properties is the result.

Bowen Engineering is proud to have had the opportunity to cooperate in this project.

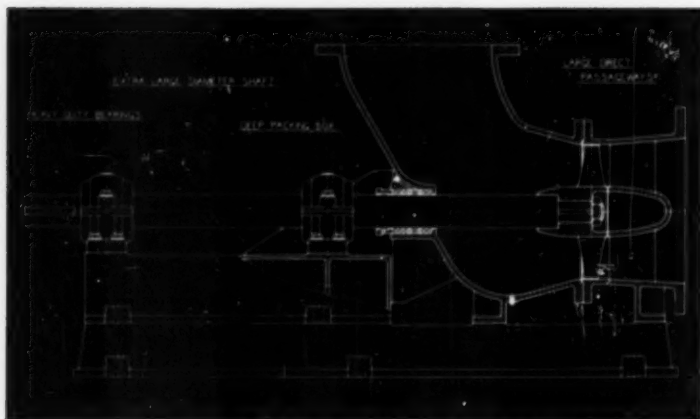
BOWEN ENGINEERING, INC.
NORTH BRANCH 13, NEW JERSEY

BOWEN SPRAY DRYERS
Always Offer You More!

Recognized Leader in Spray Dryer Engineering Since 1926



Lawrence 24" Horizontal Circulating Pump of Nickel Alloy Construction



Cross Section of Lawrence Horizontal Propeller Pump

PROPELLER PUMPS FOR THE CHEMICAL and PROCESS INDUSTRIES

Lawrence Propeller or Axial Flow Pumps are widely used to circulate large volumes of liquid or slurry against low heads as in evaporators, crystallizers, etc. This type of pump is particularly well adapted for circulating service because of its simplicity, high efficiency, and low first cost. The flow can be arranged in either direction and the casing turned to any position desired to serve as an elbow. The capacity can be closely regulated by varying the speed—very important in crystallization processes where a uniform velocity must be maintained.

Lawrence Propeller Pumps are made of the metals and alloys best suited for their ability to resist the corrosive and abrasive action of the liquid pumped.



Write for Bulletin 203-6 for summary of acid and chemical pump data.



LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS.

HORN OF AMALTHAEA

(Continued from page 20A)

but that an ever increasing demand makes it clear that it should never be taken for granted anywhere.

The report on water covered some fifteen typewritten pages. In the main it was found that there is a great need for adequate collection, analysis, and speedy publication of basic data on climate, on water, and on associated land resources; the effect of land treatment and of upstream measures for flood control needs to be analyzed; consumption studies are needed; data on the reuse of water by industry are necessary to arrive at better estimates of industrial water demands; research is needed on water treatment, ecological processes, toxicological effects of chemical pollutants, and virus transportation; collection of data on air-conditioning installations is desirable; and state and federal evaluation of present methods of pollution abatement is needed to determine progress. The collection and analysis of data on water ought to be coordinated and directed to local problems by regional centers.

No great decisions were reached at the conference, nor were there resolutions, courses of action, or even a clear-cut determination to carry on with what had been started. The conference did present, however, a unique opportunity for a mingling of workers in many fields, and the cross-fertilization inherent in the interchange of ideas must inevitably produce seeds of progress. Penetrating the fog of the future was next to impossible for the conference, and for every argument about the lack of resources and the rate of consumption, the Cornucopians would reach into history for examples of previously predicted doom and show how unfounded they were. It was certain that history abetted the optimist, and the Cornucopians were certain that the magic would never stop. Amalthaea's horn*—just a pilot plant!

PILOT PLANT MAKES FURFURAL FROM WASTE

Production of furfural from waste pulping liquor is being studied at pilot-plant level, according to an announcement by Brown Co., Berlin, N. H. The company, which supplies wood cellulose products, explains that principal objectives of the study are maximum use of wood, the company's prime raw material, and reduction of stream pollution in the Androscoggin River. The pilot-plant operation will continue for several months before a decision is made.

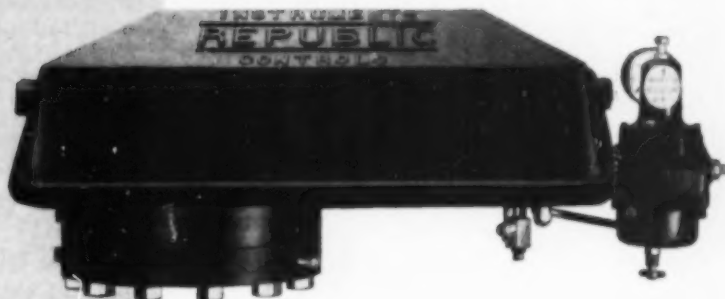
* Amalthaea—goat nurse of Zeus, whose one horn, at the wish of the possessor, would provide abundance. From this we get Cornucopia.

COMBINES MACHINE RUGGEDNESS WITH INSTRUMENT PRECISION for dependable

low
maintenance
metering

REPUBLIC

pneumatic
transmitter
for measuring
FLOW, PRESSURE,
LEVEL or
DENSITY...



Machine dependability with instrument accuracy and sensitivity! Think what this combination of features can mean in your plant—less maintenance, longer life for lowest "long run" cost, continuous accurate operation.

You get all of these benefits and more with the Republic Pneumatic Transmitter. Force-balance operation permits the use of strong rugged parts with no sacrifice in accuracy or sensitivity. Gives exceptional overrange protection.

Housed in a durable metal case, the transmitter may be adjusted for mounting at any angle, indoors or out. Its accuracy is not affected by changes in ambient temperature vibration, nor-

mal changes in supply air pressure or inaccurate leveling. Uses no mercury or purge pots. Can be used with very viscous fluids.

The Republic transmitter isolates fluids to a measuring chamber which may be supplied in a variety of corrosion resistant materials. It sends an air pressure proportional to fluid flow, pressure, level or density to reading instruments or for actuation of an automatic controller.

Republic Pneumatic Transmitters are proving their superiority in hundreds of chemical and oil field applications. Investigate their advantages for you—write for your free copy of 36 page Data Book No. 1004.

SPECIFICATIONS:

ACCURACY— $\frac{1}{2}\%$ of maximum range guaranteed for standard models.

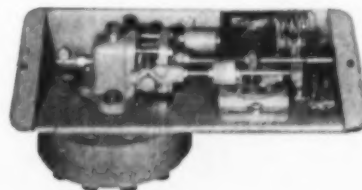
DIFFERENTIAL RANGES—Any desired span between 0-0.6" H₂O and 0-750 psi at operating pressures of 15 psig to 2000 psig.

PRESSURE RANGES—Any desired span between 0-1" H₂O and 0-2000 psig.

LEVEL RANGES—to meet almost any application.

DENSITY RANGES—0.15 sp. gravity spread for 3 to 15 psig output pressure from any base density.

Extremely wide range change is possible without change of parts. Ranges may be easily changed, suppressed, compounded or reversed.



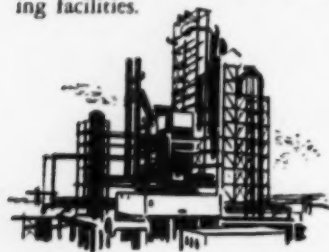
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To produce more ammonia without excessive expansion of existing facilities.



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THIS MONTH IN INDUSTRY

- Rubarite, Inc., owned jointly by The Goodyear Tire & Rubber Co., The National Lead Co., and Bird & Son, Inc., was formally dedicated recently in Malvern, Ark. The new plant manufactures a synthetic rubber powder used in asphalt for road paving.

- Colgate-Palmolive-Peet Co. became Colgate-Palmolive Co. as of Oct. 30, 1953. There was no change in corporate entity.

- West Virginia Pulp and Paper Co. has formed a new division for production and sales of its lignin products. Known as the Polychemicals Division, the new organization will be located at Charleston, S. C.

- Formation of the Zirconium Corporation of America was announced recently by its president, George R. Sylvester. Located at Solon, Ohio, the new company will concentrate on production of zirconium oxide.

- Equipment, chemical processes, and inventories of the aromatic chemicals department of Naugatuck Chemical Division of the United States Rubber Co. were purchased by Roubechez, Inc., New York, according to a recent announcement.

- The Borolite Corp. has recently been formed to intensify research and development of various metal borides by three companies: Firth Sterling, Inc., of Pittsburgh, Pa., American Electro Metal Corp., Yonkers, N. Y., and The Carborundum Co., Niagara Falls, N. Y. Initially the three companies will manufacture the borolite products, which will be marketed by the Borolite Corp., Niagara Falls, N. Y.

- Heyden Chemical Corp. announced the sale of its antibiotics division to American Cyanamid Co. on Dec. 1 for \$12,000,000 in cash; most of the inventory of the division was also sold, for 85% of the book value.

- Stanolind Oil and Gas Co. has announced the selection of the Lummus Co. to help investigate the physical condition of the Carthage Hydrocol, Inc., synthetic gasoline plant at Brownsville, Tex. No decision has yet been made as to the acquisition of the property.

- Controlling interest in the Camden Forge Co. has been acquired by United Dye and Chemical Corp., Belleville, N. J., as a step in its long-range expansion and production-diversification program.

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Turbo-Dryer

CONTINUOUS, VERTICAL, TRANSFER TYPE

for SENSITIVE PRODUCTS



High efficiency

Low maintenance

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also suitable for COOLING

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1-54

Name: _____

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DRYING PROBLEMS?

JUST WRAP 'EM UP AND SEND 'EM TO US . .

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FROM ABRASIVES TO YARNS**

**HERE ARE A FEW OF THE PRODUCTS WE'VE TESTED
IN OUR LABORATORY FOR MORE EFFICIENT DRYING**

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Apples	Flour	Printing Inks
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Bast Fibres	Grain (cooling)	Pulp
Beans	Hides	Rice
Bristles	Hair	Rubber—reclaimed, synthetic and natural
Building Materials	Kaolin	Salt
Calcium Carbonate	Latex	Sawdust
Chemicals	Macaroni	Sisal
Clay Fillers for paper	Metal Parts and Products	Synthetic Fibres
Cloth	Nuts	Textiles—raw and dyed stock
Coatings	Paints	Tobacco
Coconut	Paper & Paper Products	Waste Sludges
Cotton	Peanuts	Wool
Dehydrated Foods	Peat Moss	Yarns
Explosives	Pigments	
Fertilizers		

CAN YOU ANSWER THESE QUESTIONS ABOUT THE DRYING OF YOUR PRODUCT?

1. Is it dried uniformly, to exact degree desired — under complete control at every stage?
2. Are you getting maximum rate of production possible, yet maintaining automatically controlled, unvarying quality?
3. Is your drying process the most efficient possible — quality-wise, AND cost-wise? No steam or hot dry air waste? Using minimum floor area? And optimum bed depth? Would alternate airflow direction zones help, or radiant heat boosters, or varying temperature zones?
4. Is your product correctly pre-conditioned for most efficient drying? Have you ever compared drying curves to be certain that every important variable is controlled within pre-set limits — automatically?
5. Which type of dryer is best for your product — tunnel, pole, tray, truck, or special design?

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determine the one best commercially practical way to dry YOUR product easier, quicker, more economically? Just write us.

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CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions or Council.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before February 15, 1954, at the Office of the Secretary, A.I.Ch.E., 120 East 41st Street, New York 17, N. Y.

Applicants for Active Membership

Abrahams, Samuel A., Berkeley, Calif.
Anderson, A. G., Pittsburgh, Pa.
Boschen, Charles F., Penns Grove, N. J.
Boyer, Lee H., Idaho Falls, Idaho
Broderick, Harold M., West Springfield, Mass.
Carreras, Alvaro, Havana, Cuba
Cimino, Saverio M., Newark, Calif.
Clapp, Edwin M., Jr., Wilmington, Del.
Diamond, Irving W., Akron, Ohio
Duffie, Cornelius R., Portland, Ore.
Dunham, W. W., Jr., Westfield, N. J.

Eldridge, John Wm., Charlottesville, Va.
Erdman, Allen G., Springfield, Mass.
Fiaccone, Hubert N., Albany, Ga.
Finn, Donald W., St. Albans, W. Va.
Folsom, Richard G., Berkeley, Calif.
Fowler, Frank C., Kansas City, Mo.
Fraleigh, Fred W., Jr., Cleveland, Ohio
Francis, Leo H., Appleton, Wis.
Frischmuth, Robert W., Cleveland, Ohio
Gerges, Richard D., Huntsville, Ala.
Gerstaecker, Wm. G., Cleveland, Ohio

YOU CAN'T ALWAYS **STOP FIRE** BUT YOU CAN

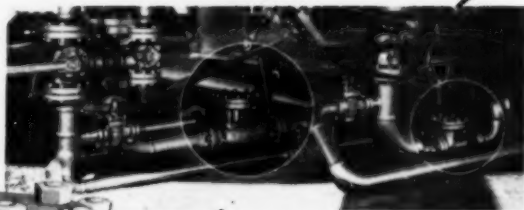
● Here's about the cheapest kind of fire insurance you can buy. Install **GREENWOOD Triple-Action Quick-Closing Valves** on all lines and tanks handling volatile or combustible products... and get effective protection against fire—day and night, year after year. Fire melts fusible link, closing valve instantly. In emergency, valve may be closed manually by remote control or by pressure or failure of air... thus preventing the spread of fire.

GREENWOOD Triple-Action Quick-Closing Valves are regularly made of cast steel with stainless steel trim. For chemical, acid, or other special services these valves can be furnished in monel, stainless steel or other alloys with proper trim for the particular service. Available in 1", 2", 3", 4", 6" and 8" pipe sizes.

VALVE MAY BE CLOSED 3 WAYS

1. FIRE MELTS FUSIBLE LINK.
2. REMOTE MANUAL CABLE CONTROL.
3. APPLIED AIR PRESSURE OR AIR FAILURE.

give your plant and equipment this added protection against the damages of fire!



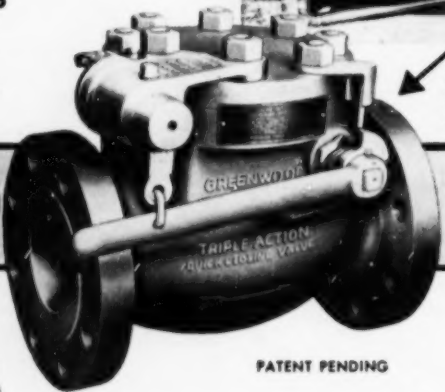
GREENWOOD Triple-Action Quick-Closing Valves in use on pressure storage tanks where highly volatile products are stored

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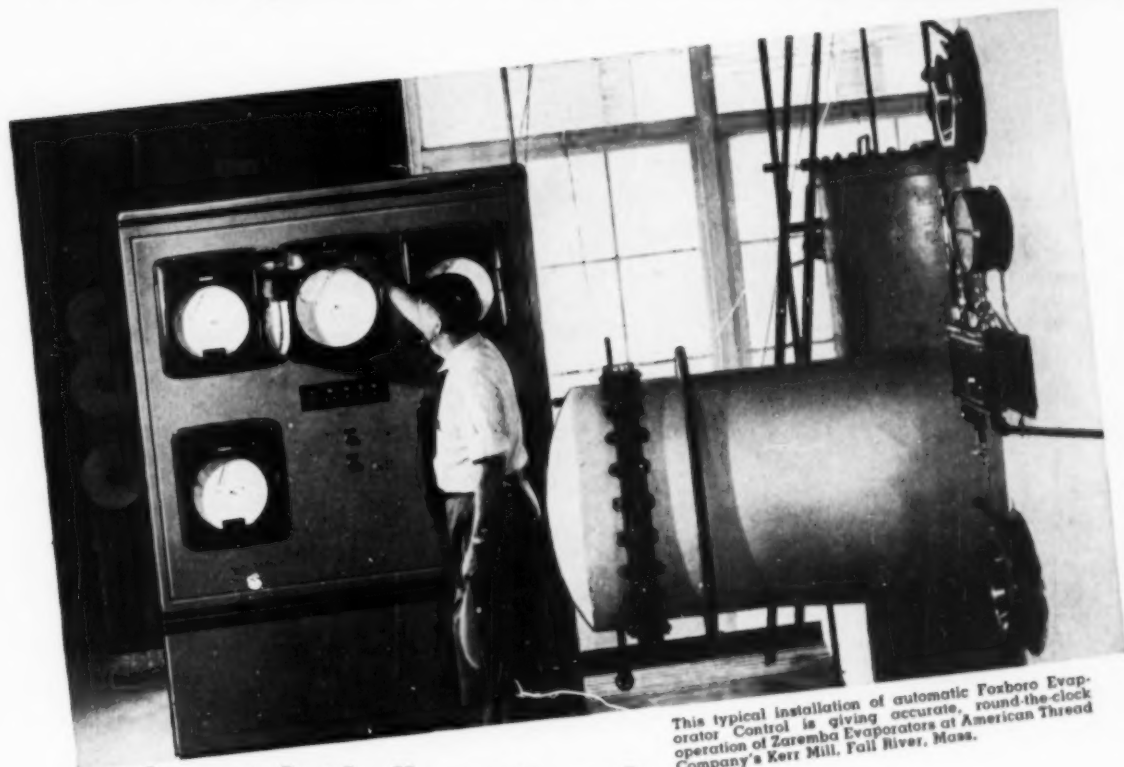


PATENT PENDING

TRIPLE-ACTION QUICK-CLOSING VALVE

Write for copy of Bulletin GV-3
showing the complete line of
GREENWOOD Valves

Control Evaporator Concentration Automatically!



This typical installation of automatic Foxboro Evaporator Control is giving accurate, round-the-clock operation of Zaremba Evaporators at American Thread Company's Kerr Mill, Fall River, Mass.

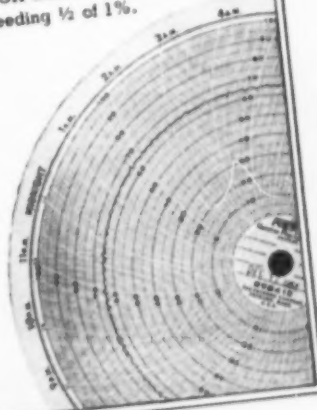
...with an individually-engineered Foxboro Instrument System

In more than 40 plants throughout the country, evaporator concentration is being held at precise values, automatically, with Foxboro Control Systems. Some of these systems have been in daily use for as long as 4 years. The principles are easily and equally adaptable to virtually any polar solution.

Foxboro Automatic Evaporator Control is based on continuous measurements of "boiling point rise" ... and on the exceptional sensitivity (1/100 of 1% of scale) of the Dynalog Electronic Controller combined with the high accuracy and stability of the Dynatherm Resistance Bulb. Pioneered and developed by Foxboro, this automatic control for evaporators offers you greater uniformity of end-product, increased evaporator capacity, elimination of spot sampling, and the release of needed manpower from purely routine tasks.

Write for engineering data sheet including full specifications and layout... and for a copy of the monograph "Quality Control in the Process Industries." The Foxboro Company, 931 Neponset Avenue, Foxboro, Mass., U.S.A.

Actual chart reproduced here shows concentration held continuously at 32 1/2% NaOH with maximum deviation never exceeding 1/2 of 1%.



FOXBORO

Reg. U. S. Pat. Off.

AUTOMATIC EVAPORATOR CONTROL

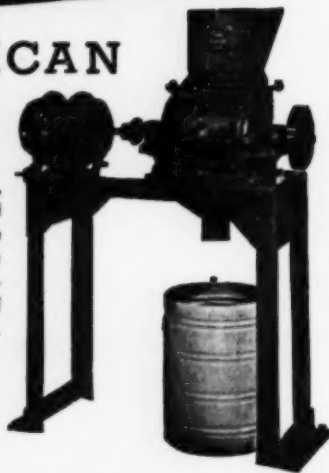
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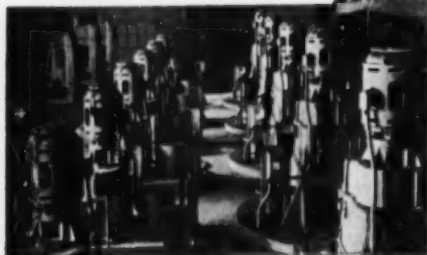
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... Main 0062

CANDIDATES

(Continued from page 60A)

Goldsmith, Fred, Cleveland, Ohio
Greenwald, William C., Lewiston, N. Y.
Gudenrath, Geo. L., Houston, Tex.
Hall, Charles R., Niagara Falls, N. Y.
Hanstedt, Le Vern E., Redondo Beach, Calif.
Howard, Owen G., Toledo, Ohio
Innes, William B., Stamford, Conn.
Jealous, A. Carleton, Oak Ridge, Tenn.
Kilgren, E. W., Tulsa, Okla.
King, Robert W., South Charleston, W. Va.
Larsen, L. V., Coshacton, Ohio
Larson, Lester L., Mendenhall, Pa.
Matter, Theodore S., Upper Darby, Pa.
Newby, Howard J., Hoboken, N. J.
North, Edward D., St. Louis, Mo.
Ogden, John W., Chatham, N. J.
Paige, David M., Idaho Falls, Idaho
Pickens, Andrew T., E. St. Louis, Ill.
Raseman, Chad J., Upton, L. I., N. Y.
Rasmussen, Leslie E., Louisville, Ky.
Rogers, Douglas A., Orange, Mass.
Sesonske, Alexander, Los Alamos, N. M.
Stopford, James C., Honolulu, T. H.
Sutton, Leslie A., River Edge, N. J.
Vander Waude, J. C., Longview, Tex.
Weisemann, Gert Hons, Whiting, Ind.
Wells, D. Maynard, Schenectady, N. Y.
York, Otto H., East Orange, N. J.
Youngquist, Orrin G., Wilmington, Del.

Applicants for Associate Membership

Anderson, Harold E. B., Chicago, Ill.
Kroll, Leonard, New York, N. Y.
Norris, William E., Beaumont, Tex.
Wilson, Walter B., Indian Hills, Colo.

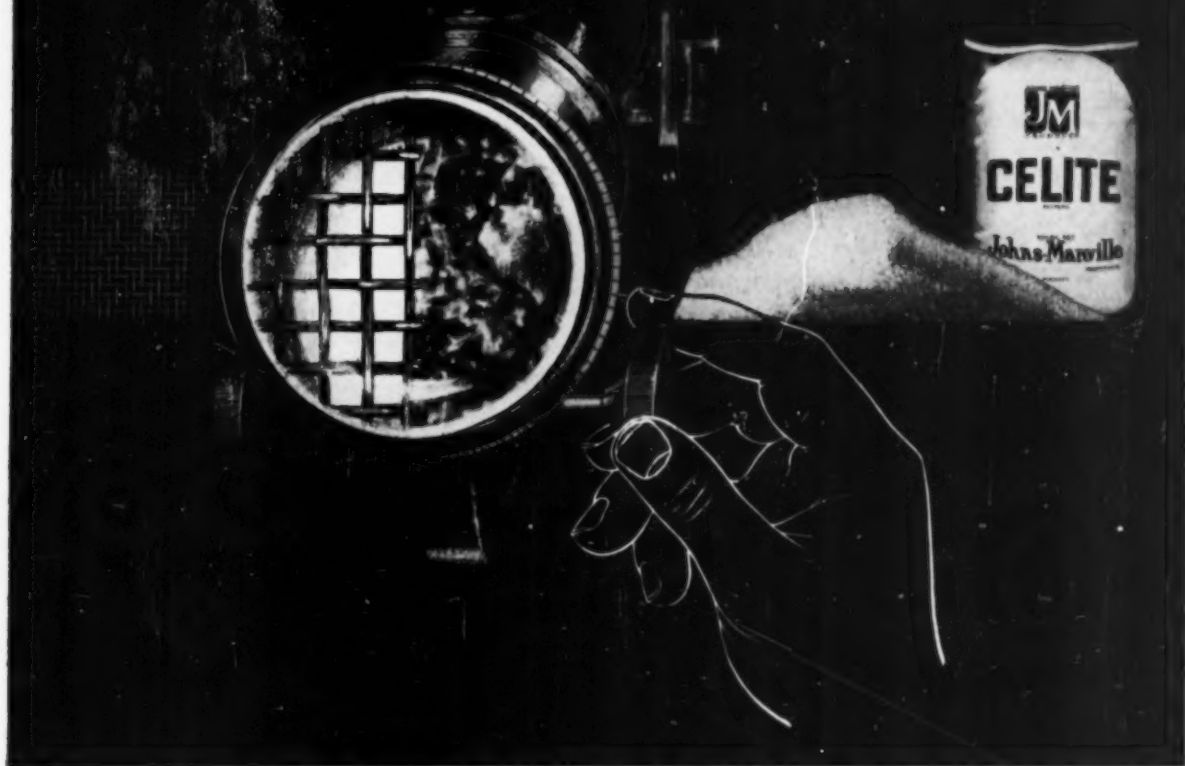
Applicants for Junior Membership

Adams, Richard L., Louisville, Ky.
Andrews, Alvin J., Bartlesville, Okla.
Arnold, Edward R., Pittsburgh, Pa.
Boer, Donald H., Bartlesville, Okla.
Bakeman, Vance Murray, South Brooksville, Me.
Baker, Robert E., N. Tonawanda, N. Y.
Bakken, James F., Teaneck, N. J.
Behrmann, Wm. C., Lawrence, Kan.
Black, E. Newbold, IV, Marcus Hook, Pa.
Breux, Glenn A., Texas City, Tex.
Brethauer, Walter H., New Haven, Conn.
Brink, Joseph A., Jr., Lafayette, Ind.
Brodasky, Thomas F., Boston, Mass.
Brubaker, David Wm., Decatur, Ala.
Buffett, S. McCray, Portland, Ore.
Caplow, S. David, Philadelphia, Pa.
Cartmell, Robert R., Crown Point, Ind.
Charlton, J. B., Decatur, Ala.
Colmenares, Carlos, Berkeley, Calif.
Cordon, Adolfo, So. Bend, Ind.
Crowther, Robert H., Crown Point, Ind.
D'Amato, Anthony S., Pittsfield, Mass.
Davies, John V., So. Charleston, W. Va.
DiPalma, Sebastian M., Waterbury, Conn.
Douden, David K., Schenectady, N. Y.

(Continued from page 64A)

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INDUSTRIAL WORK CLOTHING

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Still Good
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Worn for two weeks in a typical plant under identical conditions with shirt shown below. Corrosive dust and chemicals couldn't hurt this sturdy, rugged material.



**Ordinary
Cotton or
Wool Good
Only for
Rags**

After 2 weeks' wear in same plant, same conditions as shirt above, this is good only for the junk pile.

Outlasts Cotton or Wool Ten Times Over

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**Not Only Tough
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Carefully tailored, requires no ironing, dries wrinkle free and repeated washings do not affect it. The only work clothing men don't mind wearing on the street.



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CANDIDATES

(Continued from page 62A)

Dunaway, B. E., Jr., Waynesboro, Va.
Eads, James C., Akron, Ohio
Evans, Charles, Jr., Pittsburgh, Pa.
Evoy, Martin, III, Baederwood, Pa.
Finneran, Walter A., Niagara Falls, N. Y.
Freitag, Walter E., Louisville, Ky.
Furman, Daniel W., New York, N. Y.
Gautreaux, Marcelian F., Baton Rouge, La.
Gill, J. L., San Francisco, Calif.
Gillett, Jack C., So. Haven, Mich.
Goode, Thomas Lee, Austin, Tex.
Grabentetter, Nelson W., Rochester, N. Y.
Haire, Robert M., Grand Island, N. Y.
Hall, James F., Jr., Carnegie, Pa.
Haring, Leon H., Chicago, Ill.
Hersh, Leroy S., Upton, L. I., N. Y.
Hite, Sam C., W. Lafayette, Ind.
Hockstra, Gerald B., Chicago, Ill.
Hunerwadel, Otto K., Jr., Dumas, Tex.
Jordan, Edward T., Jr., Port Arthur, Tex.
Juhl, William G., El Dorado, Ark.
Katona, Alex, Cleveland, Ohio
Kaufman, Joseph, Brooklyn, N. Y.
Kessler, Richard E., Allen Park, Mich.
Kingrea, C. Leo, Baton Rouge, La.
Kopp, Marvin, West Stockbridge, Mass.
Koster, J. K., South Charleston, W. Va.
Kuerston, Richard D., Dewey, Okla.
Lee, Robert E., N. Weymouth, Mass.
Lieder, W. Donald, Charleston, W. Va.
Mattia, Manlio M., Philadelphia, Pa.
Mayes, James H., Park Forest, Ill.
McGee, Henry A., Jr., Atlanta, Ga.
Miller, Douglas, Brooklyn, N. Y.
Miranda, Bienvenido T., Quezon City, Philippines
Myers, Hugh L., Springfield, Pa.
Myers, Paul K., Brentwood, Mo.
Nirmaier, Earle A., Maplewood, N. J.
O'Neill, Frederick A., Stamford, Conn.
Palombo, Lewis P., Bruin, Pa.
Parr, J. Fred, Detroit, Mich.
Proffitt, Arthur C., Bay City, Mich.
Rood, Leonard D., Newark, N. J.
Scarborough, Ray, Milford, Del.
Schoeffel, David E., Springfield, Mass.
Schweitzer, O. R., Oak Ridge, Tenn.
Shaffer, Michael R., Alliance, Ohio
Sheard, Eric A., Belleville, N. J.
Steinacker, Warren R., Claymont, Del.
Sujata, Andrew D., Monterey Park, Calif.
Taylor, Orris W., Lakewood, Ark.
Uhland, Keith L., Orange, Tex.
Walsh, Chester J., Hollis, N. Y.
Wheeler, Joe, New Orleans, La.
Williams, Curtis C., III, Emeryville, Calif.
Young, Robert M., Canton, Ohio



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1000 lbs. of phenolic resins
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DIAMOND ALKALI JOINS ATOMIC REACTOR GROUP

Diamond Alkali Co., Cleveland, Ohio, has announced its participation as the chemical partner in the industrial study team of Foster Wheeler Corp., New York, and Pioneer Service & Engineering Co., Chicago, organized by the Atomic Energy Commission's nuclear-reactor development program.

The Commission also approved the participation of Pittsburgh Piping and Equipment Co. as consultant to the group in the piping, metallurgy, and fabrication field. The group will continue for the next six months activities already under way.

BATTELLE STUDIES READING ROBOT

An electronic machine to help the engineer to search the literature of his field is being developed at Battelle Memorial Institute, Columbus, Ohio. Eventually, the institute reported, machines able to scan up to five million published documents an hour and identify those relating to a prescribed information need may be possible. The machine will not, however, have the ability to read, cautioned Clyde Williams, president of the institute, who added, "The machine will in fact be a moronic robot." Widespread use of the machine, Dr. Williams explained, would require a "machine language," symbols appropriate for machine use, in which abstracts covering specific fields of knowledge might be indexed.

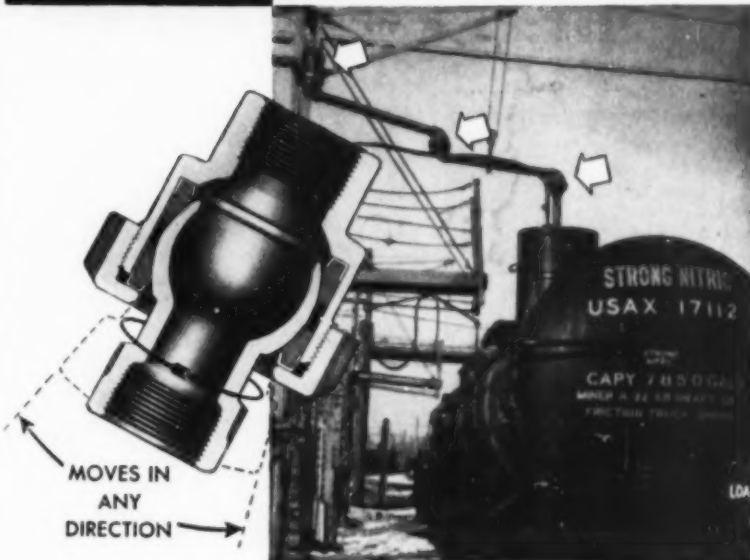
INSTRUMENTATION TO BE DISCUSSED AT FLORIDA U.

The Fifth Annual Southeastern Symposium on industrial instrumentation will be presented from Feb. 1 to 3, 1954, by the Department of Chemical Engineering, Engineering and Industrial Experiment Station, College of Engineering, University of Florida, in cooperation with the Instrument Society of America. Meetings will be held at the university in Gainesville, Fla. Topics will include the application of instrumentation to automatic chemical feed systems, variable head vs. variable area flow-rate measurement, plant efficiency and instrumentation, liquid level control. There will be demonstrations and displays of the latest developments in industrial instrumentation and a tour of the university experiment station.

Further information may be obtained from Professor R. C. Specht, department of chemical engineering, University of Florida, Gainesville, Fla.



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1. **MAXIMUM FLEXIBILITY.** Up to 40° side flexibility with 360° rotating movement.

2. **CHEMICALLY INERT GASKETS.** Barco offers a choice of seven types of gaskets including No. 11-CT for corrosive service. No lubrication required.

3. **NO METAL-TO-METAL CONTACT BETWEEN MOVING PARTS.** An important Barco advantage where corrosive chemicals are present, either externally or internally.

4. **STAINLESS STEEL BODIES.** Also regularly furnished in Malleable Iron, Steel, Bronze, Aluminum, and Magnesium. Other special alloy joints to order.

5. **MANY STYLES AVAILABLE.** Angle or straight; threaded or flanged connections. For pressures to 7,500 psi; temperatures to 1000°F. 15 different sizes, 1/4" to 12".

—when you need movable joints in piping handling

CHEMICALS

The above photograph shows BARCO BALL JOINTS used to provide flexibility in Nitric Acid Tank Car Loading Lines at the Joliet, Ill., Arsenal. This is but one of many installations in industrial plants where Barco joints are used to allow movement in piping conveying acids, alkalies, and solvents—as well as steam, air, oil, gas, or water.

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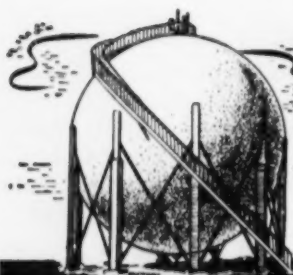


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SURVEY

(Continued from page 44A)

Call on local sections more to carry national load.

The National dues of membership should include the allocation for local chapter membership. I believe this would encourage closer relations across the country.

List addresses of all local sections in C.E.P. sometime.

Complaints of lack of interest from National A.I.Ch.E. towards fostering locals in Canada. As a result A.I.Ch.E. will probably lose considerable number of members.

4. Economic Status of Engineers

Economics is apparently an important subject. The number and the character of the comments received give the impression that this aspect in the life of the engineer is more important than the figures would indicate. In a previous article it was pointed out that the comments might represent a large group or only a small minority opinion. They cannot be extrapolated to the membership as a whole since everyone was not asked for an opinion on the questions raised in many of the comments. Hence, their importance must await additional information.

In a previous article and in the first portion of this article, figures and charts show the earnings of engineers as reported in this survey. The reader may judge whether the salary curves presented are high, low, reasonable, or unreasonable. Some of the pertinent observations made from a study of the data and from correlations with other questions were:

1. Salaries increase with years of experience.
2. Salary levels vary depending upon a man's performance.
3. With the exception of differences in starting salaries, differences in academic degrees are discounted in about 10 years.
4. There appears to be no appreciable difference in income depending upon the size of company (with few exceptions).
5. The management group is highest paid. The teachers are lowest paid. Other groups are intermediate as shown in Figures 1 and 2 of this article.

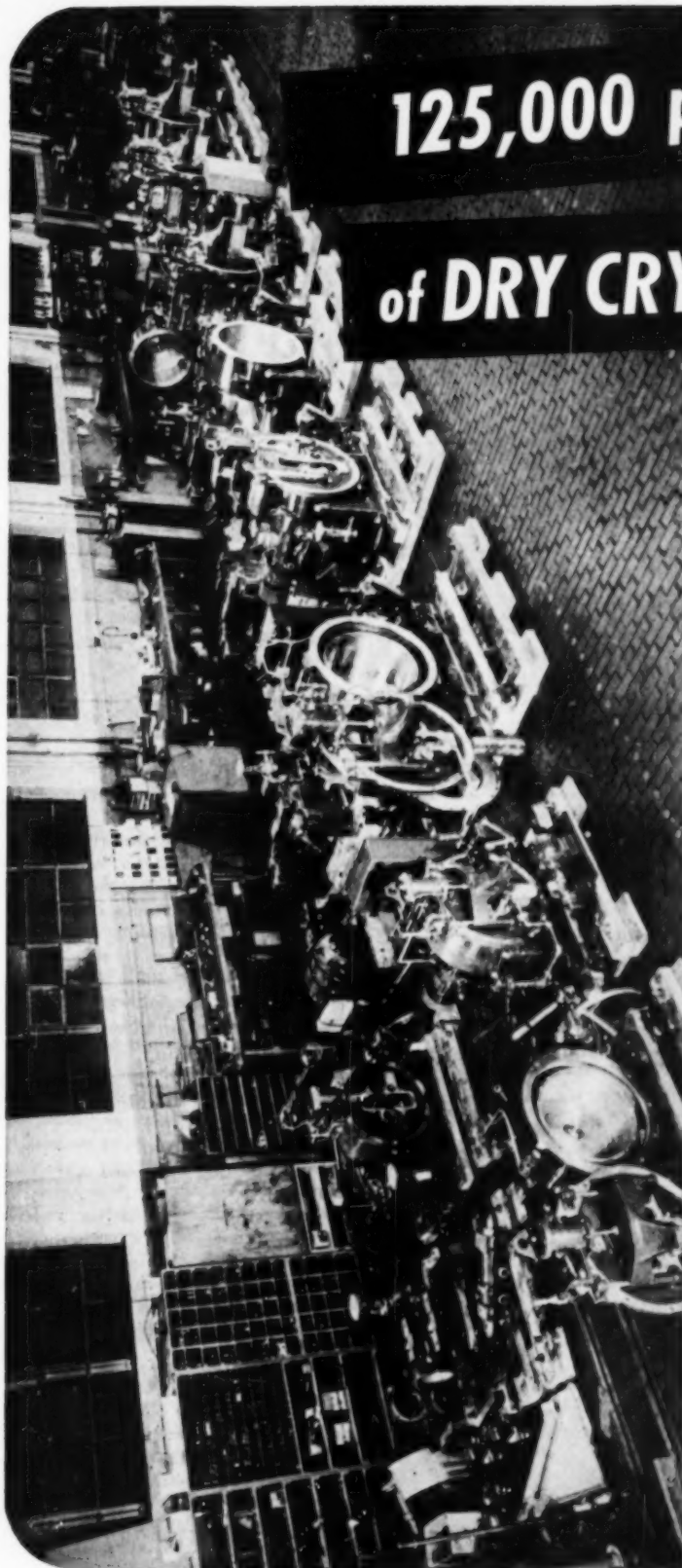
Regardless of the factual data, the following comments are typical of many received.

Serious reservations about the present policy of beating the bushes to get more engineers. Will tend to be more engineers than jobs. What is wrong with the law of supply and demand?

Only by adequate remuneration can industry attract the engineers it needs in the future.

Recommend throwing out all articles and items about the shortage of engineers unless the articles specify the duty of the engineer in question and the salary at which he is not available.

(Continued on page 68A)



125,000 pounds of DRY CRYSTALS per hour!

These 14 Super-D-Hydrators will produce approx. 900,000,000 lbs. of crystals in the next 12 months.

... ammonium sulphate, adipic acid, sodium bicarbonate, naphthalene, acetylsalicylic acid, sodium sulphate, sodium chloride, polystyrene, para xylene... to mention but a few of the crystals being dehydrated in Sharples Super-D-Hydrators.

The 14 machines recently photographed on the assembly floor of the Sharples plant are mute evidence of industry's increasing recognition of the extreme flexibility and economy that the Super-D-Hydrator offers. Eleven of those shown are the C-27, with capacity ranging up to 8 tons of dry crystals per hour, three are the C-20, with capacities up to 4 tons per hour.

The Super-D-Hydrator is what its name implies—industry looks to Sharples for extra profits in crystal dehydration.

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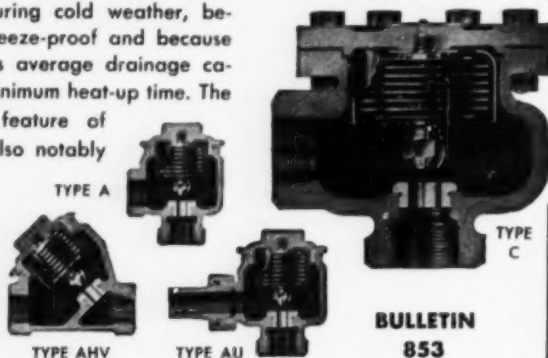
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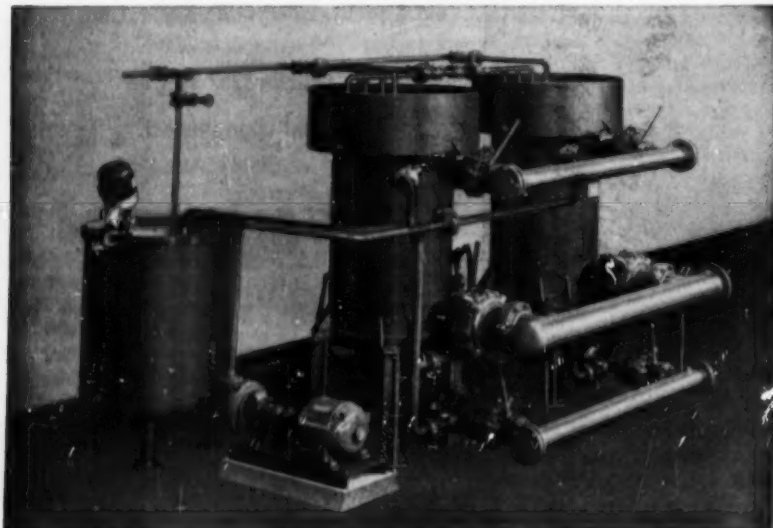
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Write for Bulletin No. 431

R. P. ADAMS CO., INC. 240 PARK DR. BUFFALO 17, N. Y.



SURVEY

(Continued from page 66A)

Actively campaign for higher salaries for engineers. Campaign to get engineers out of non-technical positions, i.e., better manpower utilization.

Do not receive commensurate pay to other professions. Apprentice programs offer more. Salaries in teaching profession are too low.

Financial remuneration is not in line with other professions.

Stress welfare of practitioners, not the profession.

The Institute should take more interest in the individual, especially in such matters as salaries and professional status.

More emphasis on opportunities in the field rather than comments regarding high starting salaries for new members.

5. National Meetings and Problems

Concerning the National meetings and general problems of the Institute, some of the more thought-provoking comments are repeated here to serve either as a guide for future action or as a basis for changes.

Symposia are tops.

Have more regional meetings, the annual is too big if more than one hotel is required.

Attempt to get permission to have more members make plant inspections during national meetings.

The cost of attending meetings has been a matter of some concern to many members, especially Juniors whose income is not as large as some of us older Active members. The cost of the Awards Banquet has risen to a point where even some of the Active members shun it.

Cost of regional and national meetings is too high for a man not on company expense account.

More consideration should be given to ventilation during sessions.

Like well-planned activities arranged for most national and regional meetings.

It is time to consider some subdivisions, such as petroleum, metallurgical, heavy chemicals.

National meetings should be spread over several sections every year to lower expenses of those attending, especially college professors who must pay their expenses. Suggest the Institute help defray expenses on some such cases where the professors might make worthy contributions.

Suggests a Canadian dinner at meetings of the Institute.

Information was obtained on three other general topics though, for the most part, these were not particularly controversial. Public Relations, Liberal Arts and Licensing of Engineers were subjects for some comment, and some factual data were also obtained.

6. Public Relations

This, like virtue and prosperity, was favored by all. Some typical comments received were:

Unending effort is needed, both nationally and locally, to enhance the stature of the engineer in public opinion.

Join other societies to enhance professional standing, stimulate interest in social and economic problems.

Institute doing an excellent job toward better recognition by the public of the role of engineers.

Believe the public needs more information about the chemical engineer, what he does, and what he is prepared to do.

Take a rather dim view of the Public relations Committee insofar as it is attempting to publicize the doings of chemical engineers in the eyes of the public. I like this questionnaire. But radio programs, lots of newspaper publicity, A.I.Ch.E. matchbooks, etc., they leave me cold.

7. Liberal Arts

As a ghost apparently banned by the answers to Question 14, this idea was brought to life again by two of the comments received. Their point was well taken and concur with their conclusions. Question 14 asked, "Do you wish that you had spent more time on Liberal Arts subjects at the expense of technical subjects in your academic work?" A total of 5,308 members said no, which seems emphatic and definite. Nevertheless, two comments, both from California, are submitted as contrary evidence, plus one additional comment.

Question 14 is unfairly "loaded." Liberal Arts courses should be stressed more, but not necessarily at the expense of technical subjects.

More liberal arts should be added to engineering curricula, but not at expense of technical subjects.

Think engineers are backward culturally and need more broadening of knowledge.

8. Licensing of Engineers

Licensing was fairly well considered in the replies to Questions 22 through 25. About 30% of almost 7,800 replies were from registered professional engineers. This included 48.7% of the Active members replying, 37% of the Associate members, and 17% of the Junior members. Thus it seems that the older members find registration more desirable or necessary than the younger group. Other data obtained indicated that future registration might amount to a total of 57%.

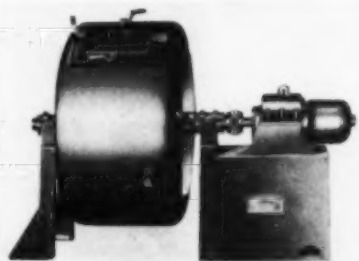
Some of the comments pertinent to this subject are:

In most states professional registration exams and rules are set up so a man just out of school could pass, but a man who is very good in his own field could not generally pass the exams.

Since we have to accept the fact that registration of engineers is required all over the nation, I would like to see the Institute take a part in promoting national registration.

Until a few years ago, a chemical engineer was recognized by his accomplishments and not

Your Grinding and Mixing Needs Well Met

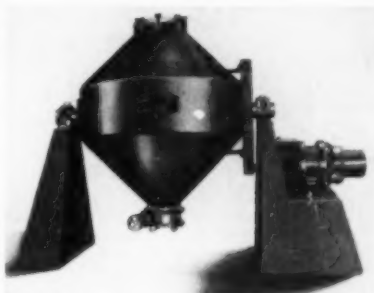
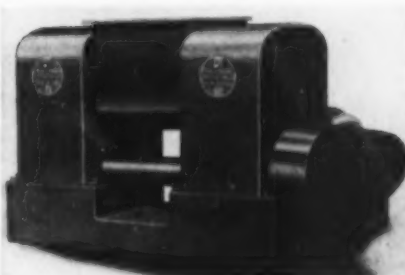


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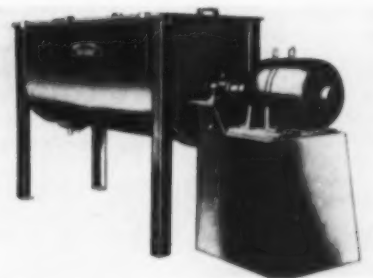
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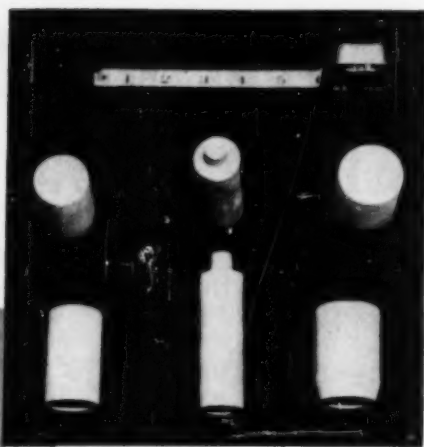
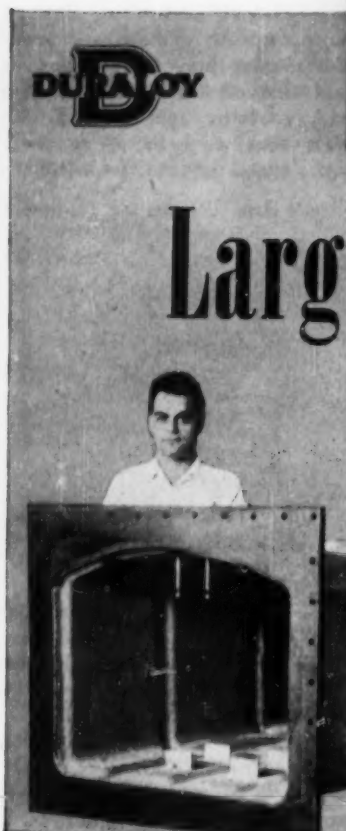


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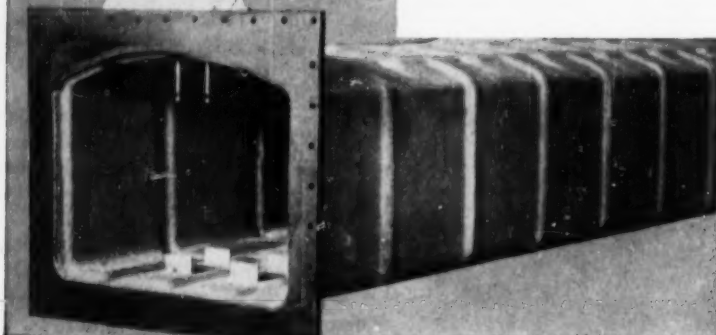
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by an act of government. The A.I.Ch.E. should take a stand against the present socialistic movement to make a chemical engineer by government fiat and then restrict his activities to one locale (state).

A.I.Ch.E. Active membership should be so qualified that holders could automatically qualify for registration as P.E. without examination.

9. Miscellaneous

A group of comments was received on miscellaneous topics some of which were of particular interest. At the risk of too much repetition a few of these are listed below.

Think the movement organizing professional engineers into a union is very dangerous and ill-advised. We must set up a group to straighten out these misguided children.

Suggest that the A.I.Ch.E. revise and modernize its "Code of Ethics" so as to give specific information about relationship of the engineer to so-called white collar unions, and thoroughly to define what is meant by a "professional engineer" when in private employ.

Also believe that engineers should spend less time talking about recognition as a profession and more time working to earn that recognition. The widespread acceptance of stream and air pollution as a necessary evil (for so long a time) is mute testimony for the fact that engineers have scarcely had the public welfare at heart. The studies in "Human Engineering" which have been projected by Carnegie Tech (I believe) are far more relevant, and engineers would be wise to take notice and emulate that approach.

Seems unfortunate that engineers have developed a profession in which they are not independent but just another commodity like sulfur or soda. The profession lacks dignity and does not share proportionately to its contribution. A real profession should be started with the university at the center. The intellectual slave market should be abolished where young men are sold into industry at the university. Positions, rendering assistance to engineers by people who are not engineers, should not be given title of engineer.

Too much in favor of industry and not individual engineer—need an A.M.A.

Employment Clearing Houses are felt to be an important needed Institute activity. These should cover all levels of interest and experience.

A simple informal employment exchange at meetings should be a useful addition. Less elaborate than ACS.

There are many young chemical engineers who do not join the Institute as Junior members because of the initial expense required. Could this fee be postponed for several years until the engineer is more or less established? As it is, there is a period after graduation when the engineer does not become associated with the Institute.

Questionnaire is a very fine idea. Could be profitably used by a local section. Hope results will be published.

(The End)



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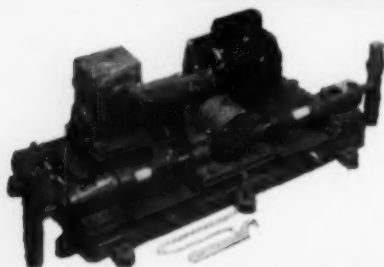


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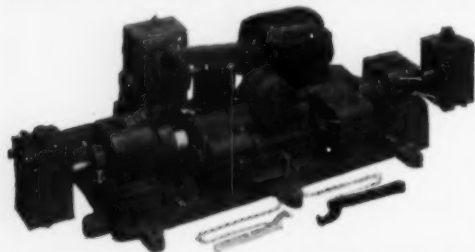
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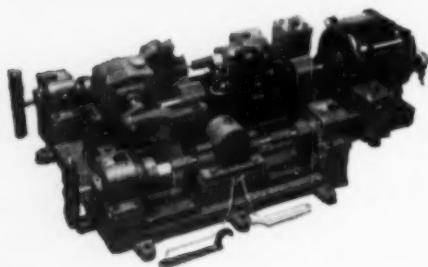
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LOCAL SECTION

A. P. Frame, first vice-president of Cities Service Petroleum, Inc., president of Cities Service Research and Development Co., and former associate deputy administrator of the Petroleum Administration for Defense addressed the New York Section, Nov. 18 on "World Oil Supply." A. Jonnard of the Publicity Committee of the section sent in news of the meeting.

The third meeting of the Northeastern New York Section during the 1953-54 season was held in Schenectady on Dec. 3. Burt Coplan of this section described a new liquid-liquid extraction device, The Pump-Mix Mixer Settler which he, with other engineers, designed at the Knolls Atomic Power Laboratory.

Names of the officers of the section for this year are as follows:

Chairman Austen W. Boyd
Vice-Chairman Richard Heitzman
Secretary Alex Schafer
Treasurer John Snyder
Executive Committee Member *

Donald Waterfield

* Three-year term. Replaces Nolan Curry who is resigning.

The Nov. 12 meeting of the Twin City Section was held in the East Room of the Curtis Hotel, Minneapolis. Thirty-two members were there for dinner and forty for the meeting.

Jerry Schwab of Engineering Sales described the old game of curling which is similar to the game of pitching horseshoes. Instead of pitching horseshoes, eight 40-lb. stones are slid on ice to a target. The skill and strategy of placing these stones on the target make this game popular with the local Curling Club in St. Paul and with fifty or sixty similar clubs over the country.

The main speaker for the evening, Professor Denbigh of Cambridge University, discussed the factors that influence the percentage of yield in batch and continuous processes. By means of graphs, charts, and flow sheets, he showed that every reaction should be thoroughly investigated before the reaction vessels are selected.

At a previous meeting William Nichols, President of A.I.Ch.E., (1953), talked on "Problems in Progressive Management."

A talk on "Chemical Plant Safety" was presented before the Cleveland Section by A. B. Pettit, manager of industrial health and safety, Davison Chemical Co. W. H. Charbonnet sent in the names of the officers for 1954. They are as follows:

Chairman-elect H. Pforzheimer
Treasurer S. Foeking
Secretary D. F. Porter

The El Dorado Section met Dec. 11, 1953. Officers for 1954 were announced at the meeting as follows:

E. C. Makin, Jr., Lion Oil Co., *chairman*

Virgil Orr, Louisiana Polytechnic Institute, *vice-chairman*

K. W. Nelson, Lion Oil Co., *Secretary-Treasurer*

M. R. Wingard, Western sales representative for Blaw-Knox Corp., spoke on "Chemofining." A hypothetical venture combining refining and petrochemical operations was described.

Thirty-four members and guests attended, according to Edward A. White.

The third dinner meeting of the 1953-54 season (Pittsburgh Section) was held at the Sheraton Hotel, Dec. 2, and was attended by approximately sixty members and their guests.

The speaker, W. E. Lusby, Jr., of the specialty products section, pigments department, Du Pont Co., spoke on "Titanium Metal—A Realistic Appraisal."

He first covered development and manufacture of primary sponge titanium, then the fabrication of this sponge into commercial articles or shapes, and concluded by explaining the present applications of the metal and what uses are indicated for the future.

Titanium is used today, Dr. Lusby said, where a high strength-weight ratio is desired at intermediate temperatures (300-800° F.). The most important of these applications would be in jet-aircraft power plants and in frame members. Future uses for titanium will probably include pyrotechnics, chemical equipment, and marine equipment.

In their account of the meeting, Messrs. Morrissey and Black referred to the speaker's use of slides showing flowsheets, fabricated equipment, test equipment, and corrosion-resistance data for titanium.

A panel meeting on "Patents and Small Business" was presented by the Chemical Engineers Club of Washington on Dec. 7, 1953, at the Burlington Hotel, with Arthur W. Crocker, assistant commissioner of patents, as moderator. Panel members were Manuel C. Rosa, executive examiner, U. S. Patent Office, R. A. Forsythe, chief counsel, U. S. Senate Selecting Committee on Small Business, and J. L. Gillman, Jr., chemical and mechanical consulting engineer.

Fred E. Frey spoke on postwar European recovery at the Dec. 10, meeting of the Oklahoma Section. Mr. Frey, assistant director of research, Phillips Petroleum Co., and G. G. Oberfell, retired vice-president in charge of research and development for Phillips and a Director of A.I.Ch.E., recently spent two months inspecting the chemical industry in Western Europe.

Mr. Frey compared the attitudes, characteristics, and industry of the peoples in the countries he visited and related them to the degree of postwar recovery of the various countries.

(Continued on page 75A)

IS LIQUID CARRY OVER-

LIMITING YOUR PRODUCTION?

AFFECTING PRODUCT PURITY?

CUTTING INTO YOUR PROFITS?

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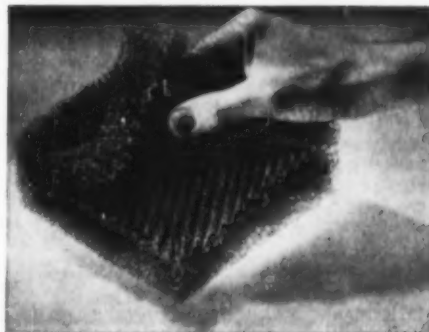
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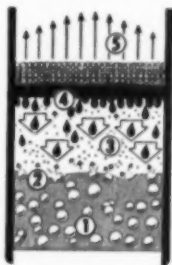
METEX MIST ELIMINATORS can be easily installed in new or existing vessels. Special housings are not needed, and they have no moving parts to require power and servicing. They will function over

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While liquid entrainment is an inevitable result of practically any processing operation involving the handling of liquids and gases together, it need no longer be considered as an unavoidable evil. It can be controlled simply, effectively and economically—by a Metex Mist Eliminator, as more and more engineers are finding from experience.



Section of a METEX MIST ELIMINATOR, opened to show construction. Factory cut to fit vessel dimensions and contour, there is no limit to the size in which they can be obtained. They can be made of practically any metal, to combat corrosion.



When a gas is generated in or passes through a liquid (1) it carries with it on leaving the surface (2) droplets of entrained liquid. These droplets are carried upward by the rising gas stream (3). As the gas continually changes direction in passing through the pad, the droplets are impinged on the extensive wire surface. Here the droplets coalesce, forming large drops of liquid which break away (4) from the pad and fall back through the gas stream. The gas (5) passes on, freed from liquid entrainment.

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FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman of the A.I.Ch.E. Program Committee

Loren P. Scoville, Jefferson Chemical Company, Inc.

260 Madison Ave., New York 16, N. Y.

MEETINGS

Washington, D. C., Statler Hotel, March 7-10, 1954.

TECHNICAL PROGRAM CHAIRMAN: George Armistead, Jr., Consult. Chem. Eng., George Armistead & Co., 1200 18th St. N.W., Washington 6, D. C.

Springfield, Mass., Hotel Kimball, May 16-19, 1954.

TECHNICAL PROGRAM CHAIRMAN: E. B. Fitch, Asst. to Res. Dir., The Dorr Co., Westport, Conn.

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.

TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: Dr. Charles H. Prien, Head, Chem. Div., Denver Res. Inst., Univ. of Denver, Denver 10, Colo.

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T.

Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Louisville, Ky., Kentucky Hotel, March 20-23, 1955.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Houston, Texas, Shamrock Hotel, May 1-4, 1955.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Annual—Detroit, Mich.—Statler Hotel, Nov. 27-30, 1955.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Head, Chemical Tech. Office, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

SYMPOSIA

SYMPOSIA FOR WASHINGTON MEETING

Mixing

Patents

Chemical Engineering in the Fertilizer Industry

Liquid Entrainment and Its Control

Chemical Engineering Fundamentals

New Metal Technology

Use of Computers in Chemical Engineering

Polymeric Materials of Construction

CHAIRMAN: C. C. Winding, Assist. Dir., College of Eng., Cornell Univ., Ithaca, New York.

MEETING—Springfield, Mass.

Process Design

CHAIRMAN: W. W. Kraft, The Lummus Co., 385 Madison Ave., New York 17, N. Y.

MEETING—Springfield, Mass.

Nuclear Engineering

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—Ann Arbor, Mich.

Agglomeration

CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.

MEETING—Glenwood Springs, Colo.

Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—New York, N. Y.

Gas Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—New York, N. Y.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

MEETING—New York, N. Y.

Fluidized Solids

CHAIRMAN: N. Morash, Tit. Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

MEETING—New York, New York

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

MEETING—Louisville, Ky.

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Chairman of the A.I. Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, one copy of the form should go to the Chairman of the symposium instead of the Technical Program Chairman of the meeting.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide to Authors, and Guide to Speakers. These cover the essentials required for submission of papers to the A.I. Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office since manuscripts are automatically considered for publication in Chemical Engineering Progress, or the symposium series of Chemical Engineering Progress, but presentation at a meeting is no guarantee that they will be accepted.

DEADLINE DATES FOR PAPERS

SPRINGFIELD MEETING—January 9, 1954

ANN ARBOR MEETING—February 15, 1954

GLENWOOD SPRINGS MEETING—May 12, 1954

NEW YORK MEETING—August 12, 1954

LOUISVILLE MEETING—November 20, 1954

HOUSTON MEETING—January 1, 1955

LAKE PLACID MEETING—May 25, 1955

DETROIT MEETING—July 27, 1955

LOCAL SECTION NEWS

(Continued from page 73A)

Mr. Frey's speech was preceded by a dinner for seventy-five chemical engineers and their wives in the Recreation Room of the Y.W.C.A., Bartlesville.

New officers for the coming year were announced as follows:

Chairman—M. F. Wirges, Cities Service Oil Co.

Vice-Chairman—J. W. Davison, Phillips Petroleum Co.

Secretary—J. J. Moon, Phillips Petroleum Co.

Treasurer—Glen Herbolzheimer, Phillips Petroleum Co.

Executive Committee Members—R. G. Atkinson, Phillips Petroleum Co.; C. C. Chapman, Phillips Petroleum Co.

At an earlier meeting held in Bartlesville, the program consisted of a panel discussion on technical writing. Participating were editors or editorial assistants of three leading petroleum technical publications:

Arch L. Foster, *Petroleum Engineer*

Henry D. Ralph, *Oil & Gas Journal*

Robert J. Phillips, *Petroleum Refiner*.

The objectives of the program were to stimulate the writing of technical articles and to determine the type and arrangement of articles desired by technical publications. Both meetings were covered by F. Morgan Warzel.

Approximately 100 members of the Chicago Section attended a dinner Dec. 9 in Morton Grove, Ill. Frank Vandenberg, vice-president of the Mallory-Sharon Titanium Corp., talked on the production, utilization and future possibilities of titanium metal. He outlined the difficulties encountered in attaining uniform properties and in producing sufficient volume for present defense and industrial needs. Titanium's strength-weight ratio at elevated temperatures and its corrosion resistance were discussed in relation to use in aircraft and ordnance production and also in chemical equipment for corrosive service.

Harry M. Betzig informs us that the talk was well received and that a lengthy question-and-answer session followed.

The Ohio Valley Section met Dec. 7, 1953, at the Engineering Society headquarters in Cincinnati.

Arthur D. Caster, wastes disposal engineer for the City of Cincinnati, talked on "Operational Problems in Sewage Disposal Works." Cincinnati's new Little Miami Sewage Treatment Plant, the first one of four sewage treatment plants to be built in Cincinnati, has recently been completed and is now in operation. The plant is so designed that its treatment process can be varied from approximately 40% to 65% purification, depending upon the amount of dilution water in



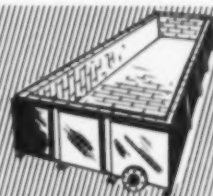
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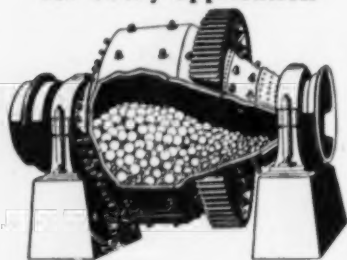
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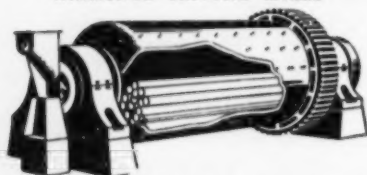
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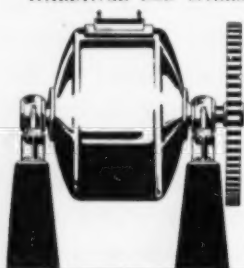
TUBE MILLS



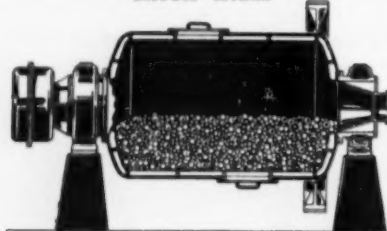
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Write for Bulletin AH-440-40



the river. Mr. Caster's discussion on the mechanical and process problems encountered in getting the plant in operation was covered by N. W. Morley.

An inspection trip through The Lubrizol Corp. in Deer Park, constituted the Dec. 18, meeting of the South Texas Section. The speaker at the dinner which followed the tour was Kermit Fischer, president of Fischer & Porter Co., Hatboro, Pa. His subject was "An Instrument Engineer Looks at the Chemical Industry." Neil H. McKay, Jr., wrote in to tell us that the November meeting, a joint affair with A.C.S.—A.S.T.M. was successful. Especially did he refer to Frederick D. Rossini's discussion on the growth of the oil industry.

The third meeting of the current season of the Philadelphia-Wilmington Section was held Nov. 17, 1953, at the School Lane House in Germantown, Philadelphia. About seventy members and friends were on hand to hear F. J. Van Antwerpen, editor of CEP, discuss the problems encountered in editing and managing that magazine. W. E. Osborn states in his report of this meeting, that Mr. Van Antwerpen left the question of the future potentials and suggestions open for audience discussion. Says Osborn . . . "It is hoped that Van can find time to give his message to many other local sections."

The Maryland Section held a dinner meeting late in 1953 at the Engineers' Club in Baltimore City at which Lewis G. Von Lossberg, consulting chemical engineer with Sheppard T. Powell Co., addressed the group on a topic of importance and interest to all—so says T. Edward Byerly, reporter—"Development and Treatment of Unusual Water Supplies."

The forty-first general meeting of the East Tennessee Section was held in two sessions—both sessions met in the foremen's room, Tennessee Eastman Co. There were twenty-six members and sixteen guests present at the first session and twenty-two members and eight guests present at the second session.

This meeting was held in two sessions to permit the presentation of a symposium on distillation, which was represented by four different speakers.

The first speaker was G. A. Akin of Tennessee Eastman Co. research laboratories, who spoke on the calculation of vapor liquid equilibrium data using Van Laar's equation of state and on the equations for the determination of the theoretical number of plates required in a distillation column. The second speaker was Warren Grubb of the Tennessee Eastman Co., whose talk was titled "Vacuum Distillation."

At the second session the first speaker was R. A. Williams of Holston Defense Corp., who

spoke on "Extractive Distillation." He discussed the correlation of experimental data for binary extractive distillations and some of the more widely practiced commercial extractive distillations.

The final speaker of the symposium was Tom Elder of Tennessee Eastman Co. engineering department, whose talk was "Instrumentation for Distillation." Mr. Elder pointed out several approaches that could be made to instrumenting distillation columns both at atmospheric and super-atmospheric pressure, depending upon whether the overhead or bottoms stream was to be controlled to a desired purity.

Toy F. Reid sent in a report of these meetings.

"Treatment of Waste Water from Petroleum Processing Facilities" was the subject of the address given by L. K. Cecil, executive vice-president, Infilco, Inc., before the Dec. 10, 1953, meeting of the Tulsa Section at the Alvin Hotel. R. J. Standliff, Jr., reports that Mr. Cecil reviewed past practice in waste water treatment and discussed recent developments in the biological treatment of wastes.

At the annual meeting of the Central Georgia Section held at the Mary Calder Club of Union Bag and Paper Corp., Savannah, Ga., the following were elected officers for the year 1954:

Chairman—J. C. Bowers, Union Bag, Savannah

Vice-chairman—J. B. Loucks, Hercules Powder, Savannah

Secretary—W. O. Ralls, Jr., Union Bag, Savannah

Treasurer—A. H. Riley, Jr., Hercules Powder, Brunswick

A. R. Bookout, Jr., reports that in other elections, he was elected to the national Institute Sections Committee and E. O. Barnes was elected to the national Public Relations Committee.

The Dec. 10 meeting of the Akron Section was held at the local Y.M.C.A. Walter M. Bruner of the polychemicals department, Research Division, Du Pont Co., gave a talk "Plastics as Materials of Construction." W. M. Otto reports that many graphs were presented to show the various physical properties of the several types of plastics in production today. Dr. Bruner gave examples of how the wide variety of properties could be used to best advantage. His talk was illustrated with a display of small articles made from different types of plastics.

Officers for 1954 elected at this meeting are as follows:

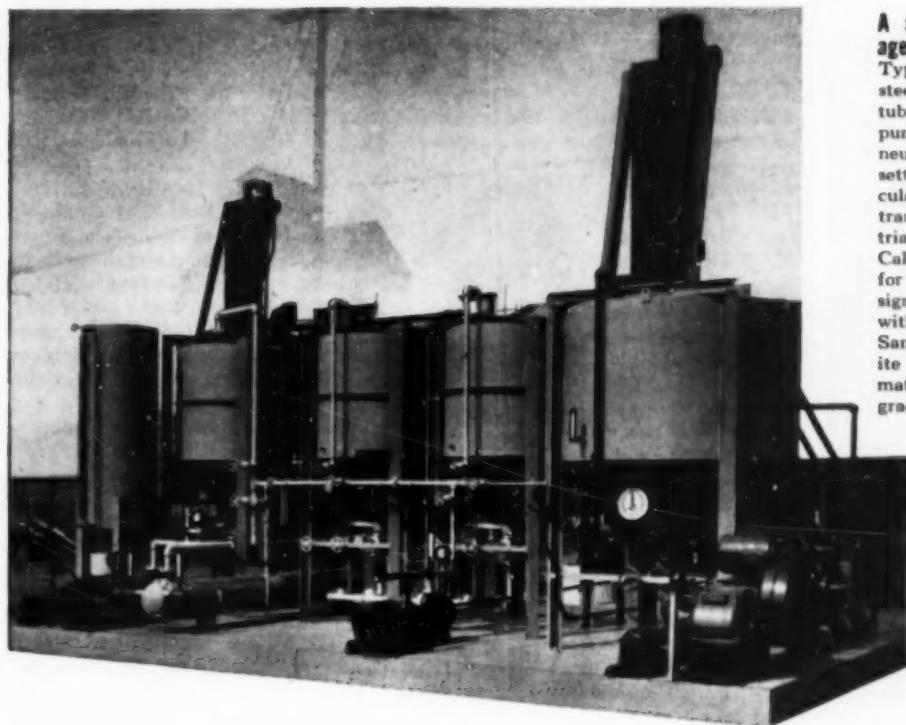
Chairman P. M. Lindstedt

Vice-Chairman W. M. Otto

Secretary H. L. Nicholson

Treasurer T. H. Rogers

—H.R.G.



A standard prefabricated "packaged" detergent plant . . . utilizing Type 316 chromium-nickel stainless steel for heat exchanger shells and tubes, sulfonator tank, neutralizer pump, seats and valves, hold tanks, neutralizer tanks, settling tanks, settling tank pumps, agitators, circulating pump on sulfonator, and transfer pump on hold tanks. Industrial Engineers, Inc., of Los Angeles, Calif., a manufacturer of equipment for production of detergents, designed this unit in collaboration with the Oronite Chemical Co., of San Francisco, producers of "Oronite Alkane" . . . a widely used raw material for manufacture of high grade detergent products.

How New Prefabricated Detergent Plant Licks Corrosion

Designed to produce indefinitely under severest conditions, this standard prefabricated detergent plant relies on an alloy containing nickel for corrosion resistance and protection against product contamination.

Peak performance, with a minimum of maintenance, is obtained by utilizing equipment fabricated from Type 316 austenitic chromium-nickel stainless steel . . .

For Type 316 stainless resists attacks by the extremely corrosive media encountered.

Throughout the process industries, low-cost operations result from using austenitic chromium-nickel stainless steels to defeat corrosion and assure maximum equipment life per dollar invested.

Stainless steels often permit making equipment lighter in weight without sacrificing strength or safety. When cold-worked they are strengthened

and hardened, and a tensile strength in excess of 200,000 p.s.i. is easily developed. Annealed, and even in the cold-worked condition, they are adaptable to many forming operations. In all conditions they are readily weldable.

At elevated temperatures, austenitic chromium-nickel stainless steels are distinguished by their strength and outstanding resistance to oxidation. At temperatures down to -300°F . they retain their toughness and unusual strength.

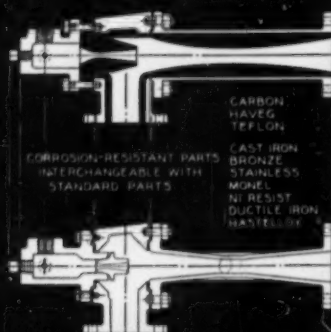
Other elements are sometimes added to give specific properties: to improve machinability, enhance scaling resistance, improve resistance to corrosion in specific, difficult cases.

Leading steel companies produce austenitic chromium-nickel stainless steels in all commercial forms. A list of sources of supply will be furnished on request.



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PEOPLE

Thomas H. Vaughn has recently been elected vice-president in charge of

research and development, Colgate - Palmolive Co., Jersey City, N. J. Dr. Vaughn resigned a similar position at Wyandotte Chemicals Corp. to accept the post. After graduation from the University of Notre Dame, with a B.S., M.S. and Ph.D., he helped organize and served as vice-president of Vitox Laboratories, Inc., South Bend, Ind. Later he was director of organic research of Carbide and Carbon Research Laboratories, Inc., first at Long Island City, N. Y. and then at Niagara Falls. He was director of organic research, Michigan Alkali Co., director of research, J. B. Ford Co., and assistant director of research of Michigan Alkali. After these two companies merged into Wyandotte Chemicals Corp., Dr. Vaughn became assistant director of research, director and finally vice-president in charge of research and development.



Charles Harold Fisher, formerly with the Atomic Energy Commission at Washington, D. C., is now a chemical engineer with the St. Louis Area Office of the A.E.C. Mr. Fisher, a graduate of the University of Missouri, worked for the Magnolia Petroleum Co., Dallas, Tex., Socony-Vacuum Oil Co., Paulsboro, N. J., and the Calco Chemical Division of American Cyanamid Co., Bound Brook, N. J., prior to his association with the Atomic Energy Commission.

Leopold A. Robillard has been assigned to the pilot plant development group at Hooker Electrochemical Co. Prior to his employment at Hooker he had been employed as a development engineer or project engineer by several Canadian firms, all located in Montreal. He received his bachelor of chemical engineering degree in 1941 from McGill University.

R. L. Powell has recently been transferred from the Titanium division of National Lead Co., South Amboy, N. J. to Titanium Metals Corporation of America, Henderson, Nevada, where he is assistant supervisor of the process research section of the technical department. Titanium Metals is a partially owned subsidiary of National Lead Co.

McADAMS HONORED FOR PUBLISHED LITERATURE

William H. McAdams is the recipient of the Worcester Reed Warner medal, American Society of Mechanical Engineers, "for outstanding contributions to permanent engineering literature." Of the fifty-eight published works written by Professor McAdams, his "Heat Transmission," used as a standard reference book, was singled out as especially meriting the Warner medal. He is a graduate of the University of Kentucky, where he also received an M.S. degree, and an honorary doctor of science degree in 1945. In 1914 he joined the faculty of the Massachusetts Institute of Technology as an assistant in analytical chemistry, receiving an M.S. degree there in 1917. He was in the Chemical Service Section and Chemical Warfare Service during World War I, and during World War II was chairman of the Subcommittee on Heat Exchangers of the National Advisory Committee for Aeronautics.

Effective Jan. 1, John A. Mullendore will direct special engineering projects at the Nitro, W. Va., plant of Monsanto Chemical Co. He received his B.S. degree in chemical engineering from Oklahoma University in 1950 and joined Monsanto's John F. Queeny plant that year in the analytical laboratory. He later held a supervisory position in the plant's manufacturing department before joining the engineering department's process section in 1951.

Roe E. Withrow, Jr., in charge of property accounting for The Dow

Chemical Co., has been elected to the board of directors of Dow Chemical of Canada, Ltd., a Dow subsidiary. He succeeds Dr. R. H. Boundy, Dow research director and a member of the parent company's board of

directors. Following his graduation from Case Institute of Technology with a B.S. degree in chemical engineering, Withrow went to Dow in 1934. He was connected with the design and initial operation of saran monomer and polymer plants in Midland from 1940-43. From 1945-46 he served in production engineering, scheduling the production of plastics and chlorinated solvents as well as government allocation of these products.



C. H. Nichols, a licensed professional engineer with twenty years' experience in the chemical and pharmaceutical fields, is now head of the chemical engineering process design division of Engineering Corporation of America, Westfield, N. J. This division offers consulting engineering services to chemical and industrial plants and special services on industrial waste treatment and water and air pollution abatement.



Marlin G. Geiger, vice-chairman of the board of directors since 1951, was recently elected president and chief executive officer of The Davison Chemical Corp. He joined the company as executive vice-president in 1947 and was elected to the board of directors that year becoming vice-chairman of the board in 1951.

His first employment was as a chemical engineer with Westvaco Chlorine

Products Corp., in 1921. He was successively advanced to assistant manager and resident manager of the company's Charleston, W. Va., plant, and before going to Davison he was a vice-president and director of Westvaco. Formerly he was a vice-president and director of United Chemicals, Inc.; president and director, W. Va. Charcoal Co.; director of W. Va. Manufacturers Association, and resident manager of Magnesol Co.

Charles J. Kentler, Jr., manager of refinery and chemical sales, Rockwell Manufacturing Co., has been named technical consultant for the entire meter and valve division. He joined the company in 1950 after three years as assistant plant manager of the chemical division of Wallace and Tiernan, Inc. Before that, he had spent seven years as chemical and development engineer for Congoleum-Nairn, Inc., Tidewater Associated Oil Co. and Tennessee-Eastman Corp., now the Tennessee Eastman Co. Dr. Kentler is a graduate of Yale University and received his Ph.D. degree in chemical engineering from Cornell University.



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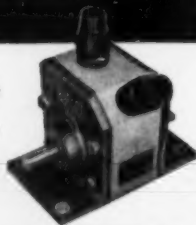
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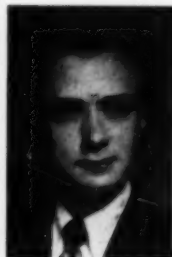
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Body Blocks: Polythelene, Bakelite, Buna N Hard Rubber, unplasticized PVC, Stainless Steel. **Flex-i-liners:** Natural and pure gum rubber, Neoprene, Buna N, Hycar, Vinyl, Compar and Silicone.

CAPACITIES from fractional to 20 gpm . . . excellent for those hard to handle corrosive fluids and slurries. Illustrated booklet on request, as well as descriptive literature on corrosion resistant centrifugal pumps, valves, pipes and fittings.

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Herbert A. Morrissey has joined the staff of the filtration department of the H. H. Thoenner Co., Pittsburgh, Pa., effective Jan. 1. Mr. Morrissey was formerly Junior Fellow on the American Iron and Steel Institute's Research Fellowship on iron ore agglomeration at Mellon Institute in Pittsburgh. In addition to his work at Mellon Institute, he has been active in publicity affairs for the Pittsburgh Section of A.I.Ch.E. since graduating from the University of Pittsburgh in 1951.



Metal & Thermit Corp., New York, announces the appointment of **Donald W. Oakley** as plant manager of its Carteret plant, effective Jan. 1.

On joining Metal & Thermit he was placed in charge of manufacturing operations for organo-tin chemicals at its Woodbridge Lab. In January, 1952, Mr. Oakley was made assistant plant manager of the Carteret plant, a position he has held until his recent appointment.

Mr. Oakley, a chemical engineer, is a graduate of Columbia University (1941).

Before joining Metal & Thermit in 1947, he was associated with Du Pont Co. as an industrial process engineer.

Bernard H. Schenk, vice-president since 1951 and a director since early last year, has been appointed president of Visking, Ltd., Canadian subsidiary of Visking Corp., Chicago. A graduate of the Illinois Institute of Technology in 1926, he joined Visking in Chicago as shift supervisor in 1928, becoming chief supervisor of the plant in 1937, chief engineer in 1944, and assistant manager of the Clearing (Ill.) division in 1947. In addition to his duties as president of Visking, Ltd., he will be in charge of Visking's international operations and will serve as a director of the corporation's international subsidiaries and affiliates.



in 1928, becoming chief supervisor of the plant in 1937, chief engineer in 1944, and assistant manager of the Clearing (Ill.) division in 1947. In addition to his duties as president of Visking, Ltd., he will be in charge of Visking's international operations and will serve as a director of the corporation's international subsidiaries and affiliates.

The appointment of **Edward C. Page, Jr.**, as technical director of the Henry Bower Chemical Manufacturing Co., Philadelphia, Pa. has been announced by that company. In 1946 Mr. Page was engaged by the Du Pont Co., where he has been employed in various capacities ever since, including five years in research and development work in synthetic films and textile fibers. A graduate of Princeton in 1942, he took his master's degree in chemical engineering in 1946 from the same university after being on active duty in the U. S. Navy.

Hallett B. Addoms has been appointed chief engineer for Niagara Alkali Co., Niagara Falls, N. Y., effective Jan. 1. Prior to his association with this company in 1945 he was associated with Hercules Powder Co. engaged in development, operation, and engineering. Mr. Addoms is a graduate of Yale University with a B.E. degree.



Leland F. Roy, formerly chemical engineer with the Tennessee Valley Authority at Wilson Dam, Ala., is now associate professor of chemical engineering at the University of Mississippi. Dr. Roy received his Ph.D. (1939), M.S. (1937), and B.Ch.E. (1936) degrees from Ohio State University.

Alex Stewart has been named vice-president, director and general manager of National Lead Company of Ohio, contract-operator of the Atomic Energy Commission plant in Fernald, Ohio. He continues as director of research for National Lead.

Robert C. Canapary has joined the staff of Esso Laboratories, Standard Oil Development Co., Linden, N. J. Dr. Canapary received his B.S., M.S., and Ph.D. degrees in chemical engineering from the Polytechnic Institute of Brooklyn.

Anthony P. Massa has left his full-time studies at the Polytechnic Institute of Brooklyn, where he has been preparing for a doctorate in chemical engineering, to resume his duties as a chemical and process design engineer with the H. K. Ferguson Co., New York. He will continue to be on the Brooklyn Polytechnic faculty as a chemical engineering instructor.



Norman Price recently joined the engineering department of the Shawinigan Resins Corp., Springfield, Mass., engaging chiefly in project engineering and design. He was associated previously with Foster-Wheeler, General Ceramics, and Du Pont. Prior to these associations, he served as an engineering officer in the Merchant Marine and as a part-time instructor of chemical engineering at New York University. He received his Ch.E. in 1944 from C.C.N.Y.



The election of **Robert K. Mueller** as division general manager, Monsanto Chemical Co., St. Louis, Mo., became effective Jan. 1. He had been general manager of the plastics division since August, 1952, serving in a number of capacities in Monsanto's organic chemical and plastics division. He joined the organic chemicals division in 1935, and later was transferred to an associated company, the Shawinigan Resins Corp. at Springfield. In 1940 he became operating superintendent of the plastics division plant and was named assistant division general manager in 1950.

Lauren B. Hitchcock, research and development consultant to the chemical and food industries, has opened new offices at 331 Madison Avenue, New York 17, N. Y. Dr. Hitchcock, chairman of the American Section of the Society of Chemical Industry, was president of the National Dairies Research Laboratories, Inc., before opening his own consulting office.

The appointment of **Charles E. Bonine** as manager of chemical product sales, The Atlantic Refining Co., Philadelphia, Pa., was recently announced. Mr. Bonine joined Atlantic in 1941 as a chemical engineer in the research and development department, the year following his graduation from Princeton University. Prior to his present position he served as home office sales manager of chemical product sales.



(More About People on page 83A)

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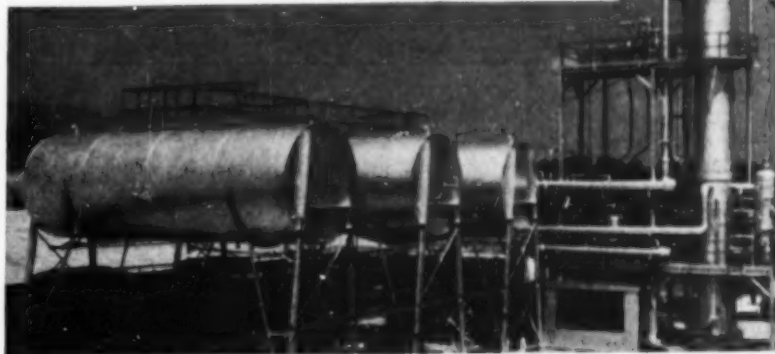
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CHEMICAL ENGINEER—M.Ch.E. with 8½ years' experience in plant design and process development of organic chemicals. Desire position requiring coordinating and planning as well as the technical ability to carry projects through to completion. West Coast preferred. Box 4-1.

PROJECT ENGINEER—P.E. Presently consultant in plant layout and equipment design. Available on consultant arrangement to firm requiring engineer for project management or assistance in obtaining new work. New York area preferred. Box 5-1.

CHEMICAL ENGINEER—M.S.Ch.E. Age 28, veteran, married, five dependents. 4½ years' diversified development experience, including two on PVC resins. Desire more challenging job. No sales or technical service. Minimum \$6,500. Prefer within 150 miles N. Y. C. Box 7-1.

CHEMICAL ENGINEER—B.Ch.E. 1950, Cooper Union. Excellent academic record including graduate work. Two years' experience production supervision, equipment design, plant maintenance; one plus years research and development. Top references. Desire responsible, challenging position. Box 8-1.

TOP-NOTCH CHEMICAL ENGINEER—Twelve years research, development, plant start-up in chemical and petroleum industry. Process design, economic evaluation, cost reduction. Currently directing pilot plant activities. Desire challenging position with aggressive manufacturer. Box 9-1.

CHEMICAL ENGINEER—B. S. 1950. Over three years' experience in organic and inorganic process development and production. Seek position with future potential in manufacturing or marketing. Married, veteran, age 28. Box 10-1.

FOR SALE—Bound Volumes of Transactions, years 1925-1946, inclusive. Box 2890, Denver, Colorado.

CHEMICAL ENGINEER—Three years pilot plant and 4½ years design engineering and construction of chemical plants. Northeast U. S. preferred. Age 32, married. Box 11-1.

CHEMICAL ENGINEER—B.S.E. (Ch.E.); M.S., U.S.A. One year industrial experience. Desire position in U.S.A. or Canada, preferably long term, teaching at university or in design, development, research section of industry. Native of India. Age 29, married. Box 12-1.

CHEMICAL ENGINEER—B.S., M.S., additional graduate achievements. Age 30, married. Navy veteran. Two years research and development, research production administration. Desire challenging position with a future. Availability prevailing. Box 13-1.

CHEMICAL ENGINEER—M.Ch.E. Three years sales engineer; eight years chemical engineer; pilot plant operator, designer, supervisor construction and operation. Put into operation commercial plants; improved operations and efficiency of old installations. Box 14-1.

CHEMICAL ENGINEER—Ph.D. 36, family. Fourteen years' experience industrial research, process development, organic and inorganic in several fields. Interested in coordination of research or technical service, or in company liaison activity. Box 15-1.

CHEMICAL ENGINEER—Age 26, B.S. 1949. Aggressive, sincere, family man with production, research, design and construction experience in building material field. Wish to indulge in field of sales or production engineering. Prefer Midwest. Box 16-1.

CHEMICAL ENGINEER—B.S.Ch.E. 1952, draft exempt. Two years' experience in design and project with large engineering firm. Desire opportunity in technical marketing or sales. Prefer N. Y. C. or Conn. but will consider any location. Box 17-1.

TECHNICAL EXECUTIVE—Age 43. Have demonstrated top qualifications in research and development, all aspects of chemical plant design, and production operations. Know processes, kinetics, patents and organization control. Box 18-1.

CHEMICAL PATENT ATTORNEY—B.Ch.E.; 1949, Tau Beta Pi, J.D., 1953. Two years' research experience in petroleum field. Three years' experience as chemical patent examiner. Desire opportunity with small chemical company. Age 27, married, veteran. Box 19-1.

CHEMICAL - SANITARY ENGINEER—Over seven years with leading manufacturer of equipment for treatment of water, sewage and industrial wastes. Experience includes 2½ years as manager of technical field service department. Desire position leading to greater responsibility. Age 30. Box 20-1.

PROCESS DESIGN—Energetic, versatile chemical engineer, Ph.D. Broad petrochemical, pesticide experience. Gaseous electrochemistry. Desire responsible position process design, pilot plant, technical service. Present salary \$9,100. Box 21-1.

CHEMICAL ENGINEER—One year's applied research and two years' production supervision experience including responsible charge of manufacturing operations. Equivalent M.S., Tau Beta Pi. Age 30. Development or production preferred. Box 22-1.

PEOPLE

(Continued from page 81A)

David L. Eynon, Jr., assistant general manager, organic chemicals division, Monsanto Chemical Co., since 1949, has been named assistant to the vice-president of manufacturing, and will be located in the executive offices in St. Louis, Mo. He began with Monsanto in 1933, first employed in the research department of the Merrimac division, Everett, Mass., and during World War II was plant manager of the government-owned Longhorn Ordnance Works at Karnack, Tex., which was operated by Monsanto. In 1945 he was named assistant to the general manager of the organic chemicals division, and acting plant manager of the company's Nitro, W. Va. operation. He became production manager of that division in 1947.

PROCESS DESIGN AND ASSISTANT PROJECT ENGINEER—M.Ch.E. Age 30. Single, energetic and alert. Six years' excellent experience in process design, project engineering, research and development; includes field construction and technical service all in chemical plants. Desire position in process design, production, and construction. Location open. Highly competent. Box 23-1.

RESEARCH AND DEVELOPMENT—M.S.Ch.E. 1951. Two years' experience in petroleum field, including pilot scale and process design development. Desire similar work with chemical company. Veteran, age 29. Box 24-1.

CHEMICAL ENGINEER—Age 31. Active member A.I.Ch.E. Seek administrative position in small production or development company. Eleven years' experience as supervisor of pilot plant, production and development and laboratory director; Atomic Energy and chemical warfare. Box 25-1.

Nonmembers

CHEMICAL ENGINEER—B.Ch.E., M.S. in Organic Chemistry and Mathematics. Rensselaer. Age 27, married. Tau Beta Pi, Phi Lambda Upsilon and Sigma Xi. Five years teaching, two years process design and development. Excellent appearance. Desire position with present challenge and future growth possibilities. Location immaterial. Box 26-1.

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SCHOENFELD & WARNER ADVANCED AT GOODRICH

Frank K. Schoenfeld, vice-president-technical of B. F. Goodrich Chemical Co., a division of The B. F. Goodrich Co., since 1946, has become vice-president-research of the parent company. Dr. Schoenfeld joined the company shortly after his graduation from the University of Michigan in 1927 as a chemical engineer. In 1942 he became director of Koroseal and plastics research. Two years later, Dr. Schoenfeld became director, technical and development of B. F. Goodrich Chemical Co.

Harry B. Warner, formerly plant manager of BFG Chemical's Avon Lake, Ohio, experimental station, succeeds Dr. Schoenfeld as vice-president-technical, directing the company's technical and development activities from the Cleveland, Ohio, headquarters. Dr. Warner joined Goodrich in Akron as a chemist in 1939 after graduation from Ohio State University. In 1948, after special overseas assignments, he was made assistant to the vice-president-manufacturing.

H. A. Hashbarger has been named supervisor of the newly formed production planning and control section in the production department, organic chemicals division of Monsanto Chemical Co. Hashbarger, who has been in the development department of the organic chemicals division, joined Monsanto in 1937 after receiving a B.A. degree in chemical engineering from the University of Illinois. He was a member of the research team which developed rocket propellants at Kayton, Ohio, and was production supervisor in the Nitro plant. From 1948 to 1952, he was development manager of the foreign department.

Raphael Katzen has initiated practice as a consulting chemical engineer in Cincinnati, Ohio. Services include assistance in management and engineering planning of new projects, and improvement of existing processes and installations in the fields of organic chemicals, petrochemicals, wood chemicals and waste disposal.

Prior to initiation of this consulting service on Oct. 1, Dr. Katzen served as manager of Vulcan Engineering, Division of Vulcan Copper & Supply Co. of Cincinnati, and will continue as a consultant.

(More About People and Necrology on page 84A)



DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15¢ a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. More than one insertion to members will be made at half rates. In using the Classified Section of Chemical Engineering Progress it is agreed by prospective employers and employees that all communications will be acknowledged, and the service is made available on that condition. Boxed advertisements are available at \$15 a column inch. Size of type may be specified by advertiser. In answering advertisements all box numbers should be addressed care of Chemical Engineering Progress, Classified Section, 120 East 41st Street, New York 17, N. Y. Telephone ORegon 9-1560. Advertisements for this section should be in the editorial offices the 15th of the month preceding the issue.

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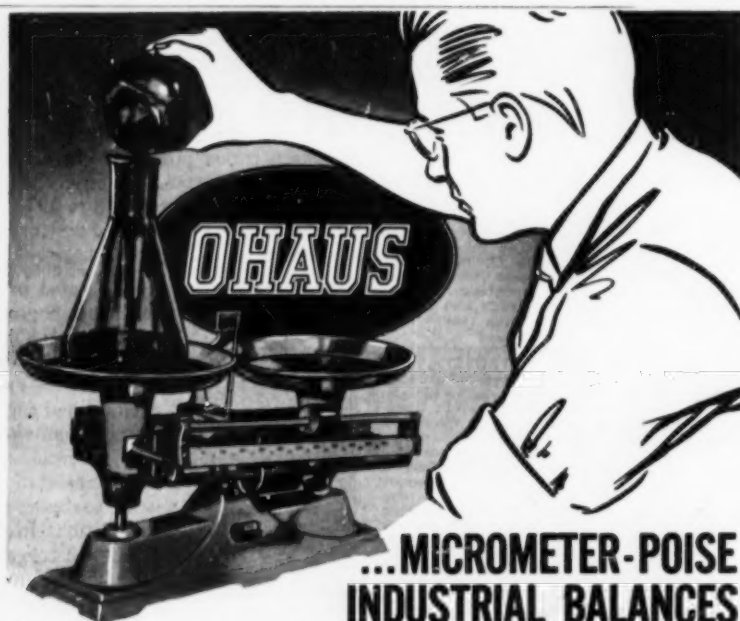
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J. F. McCamant, formerly an engineer with Calgon, Inc., Pittsburgh, Pa., is now plant engineer at the National City plant of National Gypsum Co. He received his B.S. degree from Grove City College in 1943.

Necrology

JOHN H. PERRY

John H. Perry of Wilmington, Delaware, a chemical engineer and editor of the "Chemical Engineering Handbook," died Dec. 13, in Memorial Hospital, Wilmington, after a brief illness. His age was 58.

Dr. Perry studied at the University of Maine, Northwestern University, and Massachusetts Institute of Technology. He was chemist at the Maine Experimental Station in 1916-17, and the American Agricultural Chemical Co., 1917-18.

Assistant at Northwestern 1919-20, he became consulting engineer to the Hearst papers in 1922-23, and chemist of the Helium Division, Bureau of Mines, 1923-25, when he joined the Du Pont Co., Inc., as research chemist, development chemical engineer, and technical investigator. He continued with the concern until his death. In World War I he served in the Infantry with the Ordnance detachment.

Dr. Perry was Director of the Institute (1946-48) and served as secretary of the Papers Committee (1939).

He was at various times active on the Public Relations Committee and the Program Committee and was incumbent chairman of a committee for publishing a fifty-year history of the Institute.

A. B. HETTRICK

Assistant manager of the newly formed pigments division of the American Cyanamid Co., Ames Bartlett Hettrick died suddenly Dec. 27, 1953. Mr. Hettrick was 49 years old. Following his graduation from Massachusetts Institute of Technology, he joined the Stone & Webster Engineering Corp., and subsequently held the position of chief engineer and plant manager of the Southern Mineral Products Corp. After this company was purchased in 1936 by the Virginia Chemical Corp., Mr. Hettrick was appointed vice-president and general manager of the new organization. When Virginia Chemical's titanium interests were bought by the Calco Chemical Division of American Cyanamid, he took over as works manager of the plant in Piney River, Va. Later Mr. Hettrick was promoted to assistant manager of manufacturing for the Calco Chemical Division.

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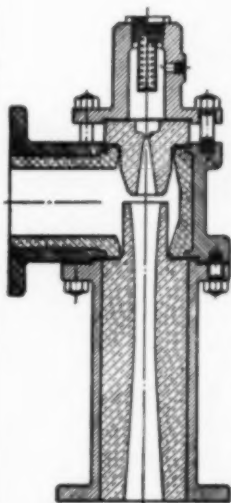
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A.I.Ch.E.

NEWS AND NOTES

Purpose: This is the first of a series of monthly news letters to members of the A.I.Ch.E. It takes the place of the feature we ran in this position last year which was written by the President to keep readers informed of Council and Committee activities. This was a popular page last year, and we hope we can do as well in keeping the profession up to date on the A.I.Ch.E. As this news page also replaces the Secretary's column, we will try to report here the news that Secretary Tyler used to cover.

Format will vary since this is an experiment in keeping you informed. It is subject to change. Don't expect the same thing every month. We also promise to be very receptive to letters of suggestion.

A new president took office January first, and his first message is this month's Opinion and Comment. **CEP** has featured editorials from officers right from the start. We feel it is one way of introducing to members the aims and purposes of a new administration.

Traditions must grow, but they must also be introduced. Bill Nichols, our outgoing president, did just that at the St. Louis meeting when he gave incoming president Chalmer Kirkbride the "great gavel of the Institute," a huge pile driver of a mallet which will be adorned with a silver plate and inscribed with the names of the presidents.

Nichols was also presented with the first "president's pin." All past presidents will receive them shortly.

Housing is one of the pressing problems facing the headquarters staff. We are now leasing some 3,300 square feet and are negotiating for 1,000 more in another building. This will require moving our addressograph, **CEP** circulation, address change, and Institute directory departments.

Council is investigating the possibilities of owning a building and the probabilities of success if money must be raised. In addition, last month it declared A.I.Ch.E.'s intent to join with the other engineering societies in acquiring a national engineering center. More on our space problem in this month's Opinion and Comment.

Two Local Sections were added at the St. Louis meeting. Council approved the appli-

cations of the Central Oklahoma and the Rhode Island sections. This brings the number of sections to 47.

Stan Lopata, new chairman of the Institute Sections Committee, shortly will begin a monthly news letter to all local section officers. Stan succeeds Curry Ford of Cleveland, who put in three years as chairman of the committee.

Committees are vital to the Institute, and our intention is to review the work of some of them on this page. While on the Institute Sections Committee, let's follow through: Ford reported to Council that there are now seventeen local groups in various stages of development which will some day achieve full section status. Objective of this committee is not to assist in the formation of new local sections only. The concept goes deeper. Information about programs, financial successes, and other local-section doings are constantly evaluated and the usable ideas are interchanged among sections. The committee also continually presents the local section picture to Council, interpreting needs and trends at the grass-roots level.

New Publication is coming. The report of Publication Committee was accepted in principle by Council, and the acceptance was implemented by the appropriation of funds from the Institute reserve. Essentially the Publication Committee recommended a new publication to carry the highly theoretical papers, plus a revised **CEP** for the process, economic, management, and news articles.

Major decisions of cost, frequency, etc., have not been decided yet. We are due to give Council a preliminary analysis in January. Publication Committee met at St. Louis and did decide some things though. Title will probably be "A.I.Ch.E. Journal," same page size as **CEP**, and three-column format. Symposium Series will continue at least for the present, and unless the volume of papers sent our way decreases sharply, we see no reason why the Symposium Series is not here to stay.

Length of papers is due for a thorough look-see. Publication Committee is now working on a general statement of information needs of chemical engineers on how papers can be reduced. Program Committee is also committed to policing paper length.

F.J.V.A.

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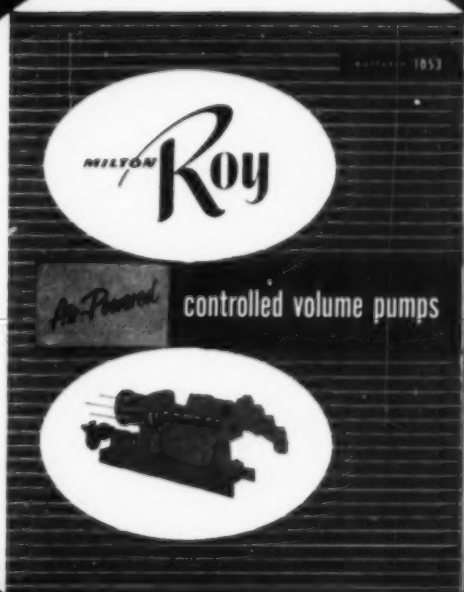
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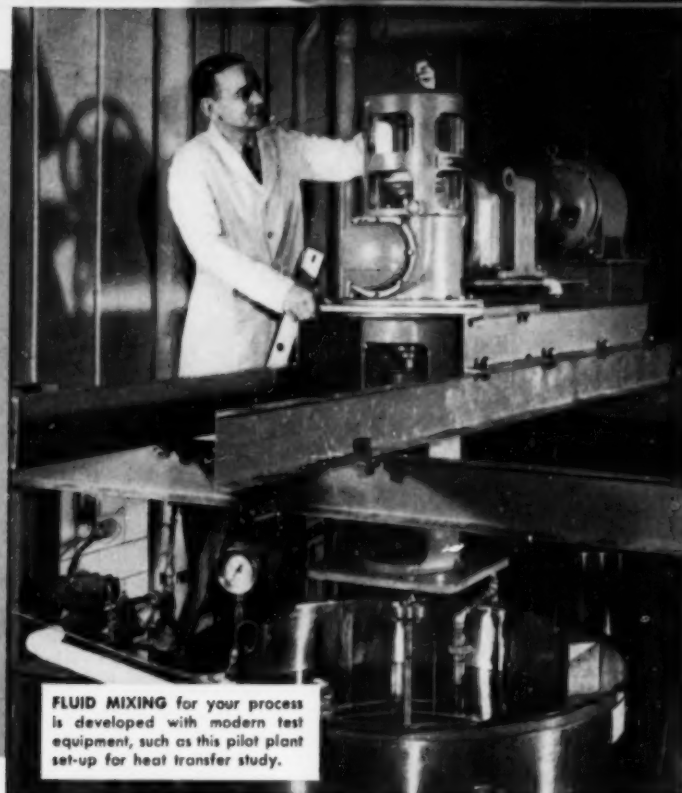
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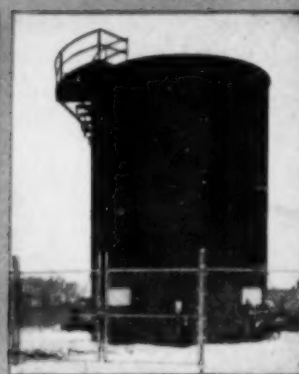
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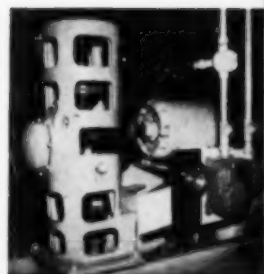
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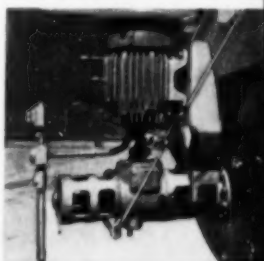
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